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Selections From 'China Today: Nuclear Industry'

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CONTENTS

Selections From 'China Today: Nuclear Industry'

81112080 Beijing DANGDAI ZHONGGUO DE HEGONGYE in Chinese
Apr 87 pp 42-45, 64-74, 166-184, 195-197, 201-202, 204-215, 227-239, 255-256, 258-263

[Selections from book "Modern China's Nuclear Industry" edited by the DANGDAI ZHONGGUO [China Today] Series Editorial Committee]

Chapter 3. All-Round Self-Reliance and the Success of the First Nuclear Test: Section 2. Speeding up the Construction of U-235 Production Line and Tackling Key Problems in the Development of the Atomic Bomb [pp 42-45]

[Text] After the CPC Central Committee issued its "Decision Concerning Certain Problems in Reinforcing Construction in the Atomic Energy Industry," construction of the nuclear industry received strong support throughout the nation. The problem that the leaders and employees on the nuclear industry front faced at the time was that regardless of the difficulties, they had to do everything possible to produce a nuclear charge for the atomic bomb and to design an atomic bomb as quickly as possible.

1. Consolidating fronts, accelerating construction of the U-235 production line

To provide a nuclear charge for the atomic bomb, China began simultaneous construction of two production lines. The first line was the U-235 production line, which employed uranium enrichment to obtain highly enriched uranium for the charge. The second was a plutonium production line that used a production reactor to obtain plutonium-239 for the charge. When the Soviet Union scrapped its treaties and shut them down, the primary link in the U-235 production line—the Lanzhou Uranium Enrichment Plant—had been basically completed and the equipment complement was rather complete. At the main link in the plutonium production line—the production reactor project—only the excavation and pouring of the concrete base plate for the reactor itself had been completed and the technical line for the reprocessing plant had not been decided upon. Given this situation, to save time in obtaining the nuclear charge needed to manufacture an atomic bomb, the CPC Central Committee instruction to "tighten up the front" was followed and the Second Ministry of Machine Building Industry decided to make the U-235 production line a "first line" project and the focus of an all-out construction effort. This included making the uranium enrichment plant a key "frontline" engineering project and striving to put it into operation as quickly as possible. The plutonium production line, however, shifted to the "second line" and construction was stopped temporarily. Attacks on key scientific research tasks were intensified despite the project stoppage in order to concentrate forces and materials to build the "first line" project. Afterwards, leaders from the Second Ministry of Machine Building Industry went on-site to provide guidance at the uranium enrichment plant and strove to solve problems at the site. At the same time, the higher authorities also provided manpower and materials guarantees. This greatly accelerated the pace of construction at the plant and the project quickly entered the production preparation stage. Preparations for the production reactor at the uranium enrichment plant were extremely complex and difficult. There were several thousand pieces of various sizes for the main production equipment and kilometers of production pipelines. The actuating medium was highly corrosive radioactive uranium hexafluoride. The pipes had to undergo fluoridization processing to assure a high degree of vacuum and cleanliness. A continuous supply of electricity, water, and steam was necessary during production. Moreover, the builders of the uranium enrichment plant had no practical experience at all in this area. To assure that it went into operation smoothly, they worked with utmost precision in all types of preparatory work prior to placing it into operation: fluoridization processing, compiling operating procedures, selecting operating programs, carrying out production and operation drills and accident exercises and so on. With approval by the CPC Central Committee, the uranium enrichment plant started trial fluoridization processing in December 1961. The work staffs combined trials and summarization and it was only after gradually gaining a grasp of all production technologies that formal and complete operation was undertaken. They began obtaining highly enriched uranium products that met specifications on 14 January 1964. When the Second Ministry of Machine Building Industry reported this achievement to the CPC Central Committee, they were congratulated by Mao Zedong.

2. Simplifying production, preparation for placing the U-235 production line into operation.

Uranium hexafluoride is the production material used in uranium enrichment plants. It is obtained by dual-fluoridization of uranium dioxide (also called uranium conversion). The former Sino-Soviet agreements stipulated that the Soviet Union would provide the uranium hexafluoride needed during the early period of operation of China's Lanzhou Uranium Enrichment Plant. Because of the Soviet shutdown, China immediately needed to produce the material itself. When the uranium enrichment plant was about complete, the question of understanding uranium conversion technologies became the most acute contradiction of the time. After earnest study, the leaders of the Second Ministry of Machine Building Industry decided to use heavy ammonium uranate as a raw material and entrusted the Institute of Uranium Ore Dressing and Smelting and the Institute of Atomic Energy with preparations for building simple experimental production facilities to prepare uranium dioxide and uranium tetrafluoride (these two projects were undertaken by the Institute of Uranium Ore Dressing and Smelting) and uranium hexafluoride (undertaken by the Institute of Atomic Energy) to satisfy the

urgent need for placing the uranium enrichment plant into operation. Moreover, they called for simplified production, testing and verification and for discovering technical principles, technical conditions, technical parameters, equipment capabilities and grasping new operating techniques. At the same time as the push for simplified production, they also were unable to relax in the construction of the uranium conversion plant. At the time, this method was figuratively called "riding a donkey in search of a horse."

Preparations for construction of the simplified production facilities progressed quickly. The leaders, technicians and workers in the Institute of Atomic Energy and the Institute of Uranium Dressing and Smelting who were responsible for this project had an intense desire to provide the raw material for the atomic bomb as quickly as possible and they displayed a selfless enthusiasm for their work, labored hard every minute and every second and fought the battle day and night. In only 3 months' time they completed the design, civil engineering and installation of the simple uranium dioxide production facility and the first loading to test the equipment was successful. At the same time, they also established an impure element spectrum analysis method. Preparations for construction of the simple uranium tetrafluoride production facility were begun in October 1960 and it was finished and in operation 2 months later. The completion and operationalization of the two simple production facilities provided materials conforming to specifications for the second work procedure. Next, the simplified uranium hexafluoride production facility underwent trial production in December 1960 and products meeting specifications were obtained.

The completion of the simplified production facilities not only provides timely supplies of some of the raw materials needed in the uranium enrichment plant when it went into operation but also trained a large group of technical cadres and workers and derived the crucial technical data and technical parameters for organizational preparation and technical preparation for placing the uranium conversion plant into operation.

3. Organizing attacks on key problems and mastering the basic theory and key technologies for the atomic bomb.

Development of the atomic bomb involved multidisciplinary and highly synthetic work. It required joint efforts and cooperation by high-level S&T personnel in many specializations. The central authorities gathered together advanced and middle-level researchers and engineering technology personnel from every sector, region, institution of higher education and scientific research institute in China to establish the Beijing Institute of Nuclear Weapons. They utilized the simple and crude conditions of the time for research and experimentation in theoretical physics, explosion physics, neutron physics, metal physics, projectile ballistics and other areas. The Second Ministry of Machine Building Industry worked closely to organize the creation of experimental conditions, allocation of forces, cooperation within and outside the ministry and other areas. Explosion physics experiments were carried out. The [Beijing] Institute of Nuclear Weapons had no [testing] site of its own at the time, so discussions were held with the People's Liberation Army Corps of Engineers to borrow a firing range in the suburbs of Beijing. Experiments for research on neutron physics were carried out using the instruments and equipment of the Institute of Atomic Energy and in cooperation with some of the scientific research personnel of the Institute of Atomic Energy. In consideration of the many work procedures involved in manufacturing the nuclear components of the atomic bomb as well as the enormous difficulty and the need for research at the earliest possible date, the personnel responsible for component processing in the nuclear component production plant were centralized in the Beijing Institute of Nuclear Weapons for a joint assault on key problems.

The most important of the key problems related to the atomic bomb was the need to master the basic theories and key technologies. The leadership of the Second Ministry of Machine Building Industry and the Beijing Institute of Nuclear Weapons focused on this topic throughout their work. Song Renqiong [1345 0117 4522] and Liu Jie [0491 2638] went often to the Theory Department at the Beijing Institute of Nuclear Weapons to check on and guide the work. Song Renqiong encouraged the theoretical researchers to work hard to develop the atomic bomb. The personnel engaged in the theoretical research did not disappoint the hopes and great trust of the party and the people and they intensified their theoretical calculations. After more than a year of repeated calculations and testing, they eventually obtained a large amount of valuable data and they also established clear physical diagrams of the interrelationships between each of the types of materials. They gained a thorough understanding of the compaction process and made significant advances in design work for the atomic bomb.

The work to attack key problems with the atomic bomb was begun in 1960 with the organization of forces to explore scientific laws, and by early 1961 it entered the important stage of a need to decide upon basic theories and key technologies. At this important time, there was a need for comprehensive analysis of the large amount of exploratory research and experimental data to facilitate intensive research and clarify certain key technologies and theoretical questions on the basis of the understanding already gained and make concentrated breakthroughs. By the end of 1962, a great deal of theoretical calculation and analysis provided a rather systematic understanding of the dynamic laws and functions of the enriched uranium used for the nuclear charge in an imploding atomic bomb. In the area of experimentation, a basic understanding was gained of important measures for obtaining implosion as well as the main laws and

experimental techniques. A major effort was made to gain a grasp of explosives technologies and the refinement and shaping of the nuclear material, and they developed an automatic control system. In addition, a comprehensive understanding was gained of bomb design and the ballistic laws of a aerial nuclear bomb, and three major experiments were completed basically in accordance with the original plans. They were a theoretical design and explosion physics experiment, which provided the technical preparations for atomic bomb modelling experiments and atomic bomb product technical designs.

Chapter 4. Obviating Interference and Advancing From Victory to Victory: Section 2. Stepping Up Development of a Nuclear Power Plant for Submarines [pp 64-74]

[Text] Nuclear submarines have good concealability and flexibility, a fast cruising speed, great endurance, long submergence periods, a strong attack capability and other advantages, and they have become the core and standard for modern strong naval equipment systems. While developing nuclear weapons, every nation with a nuclear capability has worked to develop a nuclear submarine.

China began organizing forces in 1958 to develop a nuclear submarine. The document "Concerning New Technical Questions in the Development of Naval Nuclear Submarines" which was submitted to and approved by the CPC Central Committee decided to make the Second Ministry of Machine Building Industry responsible for "reactors used in nuclear submarines and their control systems, protective equipment and other research and design tasks." After China's first successful nuclear test in October 1964, the task of developing a nuclear submarine was intensified and became the order of the day.

1. Proposal and determination of design programs.

A power reactor for a nuclear submarine is a technically complex and very difficult project. In consideration of the CPC Central Committee's decisions, the Navy and the Second Ministry of Machine Building Industry established their respective special organs in 1958 and organized young S&T personnel to study this sophisticated technology. The conditions at the time were rather poor, and there was no technical data nor the necessary experimental facilities and modern computing tools, so China had to depend entirely upon its own exploration and creation conditions. On the basis of an examination of fragmentary information from foreign nations, the scientific research personnel responsible for attacks on key tasks concerning power reactor technologies derived primary programs and parameters for a power reactor after repeated research, calculations and debate. Afterwards they did a large amount of work and completed the first draft of the program design in June 1960. At the same time, they also established a research base area and carried out discussions and surveys of selected aspects of problems involved in constructing a land-based modelling reactor.

However, the economic difficulties in China during the early 1960's shrunk the battlefront of capital construction and required first of all that forces be concentrated to develop the atomic bomb and guided missiles. Added to the fact that the uranium enrichment plant was not yet in operation, considerations from the perspective of supplies of enriched uranium also made it difficult to satisfy the needs of the nuclear submarine. For this reason, the state decided that nuclear submarines would not be included in reactor construction plans, but a certain amount of technical forces were retained, and research and design work continued.

Afterwards, although nuclear submarine research organs underwent several changes that caused many problems in the work, S&T personnel in all areas were still resolute in their endeavors. They use the information and experimental research achievements they had grasped and gradually established several facilities for research experiments. On this basis, the Second Ministry of Machine Building Industry proposed a revised program for the design of a power reactor for a nuclear submarine and submitted it to a special commission of central authorities in July 1965 after examination and revision by experts in the relevant fields. By that time, China had carried out two successful nuclear tests and the uranium enrichment plant had been completed and was operating. This showed that nuclear science and technology and industrial levels in China had laid the groundwork for a research and experiment base area for nuclear submarines. The specialized commission of the central authorities quickly approved the design program and charged the Second Ministry of Machine Building Industry with developing the work quickly and striving to complete a land-based model reactor for a nuclear submarine by 1970.

2. Construction of the land-based model reactor and research base area.

To complete a land-based model reactor for nuclear submarines and the corresponding research and experiment base areas at the earliest possible date, the Second Ministry of Machine Building Industry organized a group for re-investigation of selected aspects in March 1965 and supplemented it with a re-survey to select a site for building the reactor. In August 1965, the special commission of the central authorities approved the nuclear submarine type, the power reactor design program, the site selected for base area construction and arrangements for the pace of construction prepared by the Second Ministry of Machine Building Industry and the Sixth Ministry of Machine Building Industry. The Second Ministry of Machine Building Industry next

organized scientific research, design, construction and production personnel to go on-site, and ground breaking for construction began in September 1965.

During the early part of construction, the work proceeded fairly smoothly. Soon, however, interference by the "Great Cultural Revolution" considerably slowed the pace of project construction. Two years after construction began, only the earth and rock emplacement project for the main plant building at the land-based model reactor experiment base area had been completed. None of the 14 main laboratories in the nuclear power project research base area had been completed.

To deal with this situation, the Central Military Commission issued a special official letter in August 1967 that called on the personnel engaged in nuclear submarine development throughout China to strive for coordination, eliminate difficulties, speed up development, guarantee progress, assure quality and focus on completing state tasks. To strengthen unified leadership over base area construction, a project headquarters was set up in March 1968. On 18 July 1968, Mao Zedong also instructed forces of the People's Liberation Army to assist in construction of the land-based model reactor. At the same time, the Chinese Academy of Sciences, relevant institutions of higher education and the Machine Building, Metallurgical, Chemical Industry and other ministries as well as the relevant departments in several provinces also reinforced their support for construction of the project. From this point on, progress in the project speeded up. By the end of 1969, construction of the earthworks project for the main plant building for the land-based model reactor was basically completed, while work on the auxiliary projects continued and living and office areas were turned over for use. With the exception of some that could not obtain all of the necessary equipment, the 14 primary research laboratories were completed, including ten laboratories that had begun to produce sustained results.

3. Conscientiously carrying out modelling experiments.

On 28 April 1970 the construction and installation tasks for the land-based model reactor for nuclear submarines that China studied and designed on its own were completed in advance of schedule. The project guidance department then decided that testing would begin on 1 May 1970. The results of trial operation and adjustment as well as "cold" and "hot"criticality experiments (Footnote 1) (In reactor theory, this refers to a physical state of the reactor. In this state, there are exactly the same number of neutrons produced as there are neutrons captured, i.e., it has attained dynamic equilibrium and the reactor maintains a stable and sustained chain reaction) showed that the quality of the entire land-based model reactor project was good, that the entire reactor control system performed excellently, and that the reactor could be started up and shut down safely.

At this time, the hull of China's first nuclear submarine also was being completed, and the nuclear power plant installation stage began. The quality and performance of the nuclear power plant required additional evaluation through land-based model operation experiments. This made the success or failure of the model experiments enormously important. Zhou Enlai was extremely concerned with the experimental work and came personally to ask about the related conditions and problems. On the eve of increasing power in the land-based model ractor, a special organ was assigned to receive the relevant personnel in Beijing to make their reports.

At 2 am on 17 July 1970, the experiment to increase power in the land-based model ractor was begun. During the test, Zhou Enlai also sent special work groups to work together with the start-up and operation group to deal with problems as they appeared. Zhou Enlai made two phone calls on 18 and 20 July 1970, and called on the personnel participating in the experiments to "be unafraid and work carefully. Strengthen on-site inspections. As the experimental stage proceeds, spare no effort and be conscientious and meticulous to conform to needs." On 30 July 1970, the experiment reached full power and all of the performance indices met design requirements.

Under the personal concern of Zhou Enlai, the personnel participating in the experiments worked with great care, and the first success produced better-than-expected experimental results. The first steps of the experiments showed that: one, the design, equipment manufacture, installation and adjustment were of excellent quality; and two, that it was safe and reliable and that it had excellent self-stabilizing and self-regulation capabilities, which showed that China's first nuclear power plant for use in submarines, which had been built in our own efforts, was successful. The second stage of the experiments also showed that the reactor not only satisfied all design and full power requirements, but also that it contained considerable latent power. The reactor and the power equipment not only showed excellent safety, reliability and auto-stability during stable conditions, but also that safety and reliability were attainable under all conditions and during accident-state operation, and that it had to capacity to meet changing engine loads under actual warfare conditions. These experiments provided a reliable foundation for underwater and at-sea testing of China's first nuclear submarine.

In September 1971, China's first self-developed nuclear submarine submerged safely. After inspection by Naval ship testing, it was felt that the overall design, manufacture, power systems, observation, communications and guidance and primary weapons systems of the first nuclear submarine developed in China basically were successful and performed well. The successful trial of the nuclear submarine laid the foundation for their production of finalized designs in small quantities.

The completion and trial operation of the Chinese-designed land-based model reactor for powering a nuclear submarine and successful underwater testing of China's first nuclear submarine showed that China had grasped nuclear power technologies. This was another enormous success in the development of nuclear technology and the nuclear industry in China and followed successful tests of atomic and hydrogen bombs. It made a contribution to a stronger naval force in China and consolidation of national defense, and it also trained personnel and accumulated experience for the development of the nuclear power industry in China.

Section 3. Accelerated Construction of the Plutonium Line, Speeded Up Construction of the Third Line

After the first successful nuclear test in China, the U-235 production line was completed and went into operation, but the plutonium production line was still being built. Moreover, it had an incomplete nuclear fuel cycling system, which required that the plutonium production line be built as quickly as possible. At the time, China's first successful nuclear test broke the nuclear backs of the nuclear powers and China's struggle with the major powers in the nuclear realm intensified and became more acute. For example, people in some countries raised a public clamor and called for measures to "sterilize" China's nuclear industry. The need to prevent a sudden imperialist attack required a readjustment in the strategic deployment of the nuclear industry. Readjustment of strategic deployments, accelerated construction of the plutonium production line and accelerated construction of the third line became the most urgent tasks of nuclear industry construction for a period of time after 1964.

l. Accelerated construction of the plutonium production line.

The main aspects of the plutonium production line were two major projects: the production reactor and the radioactive chemical post-processing plant. Originally, the Soviet Union provided assistance for these two projects, but after the Soviet Union broke the treaties and stopped their assistance, things depended entirely upon China's own efforts.

Ground-breaking for construction of the production reactor project beganin March 1960. When the Soviet experts left in August 1960, only the concrete slab for the foundation had been completed and the design was far from complete. Basically, none of the key equipment had been received and work on the project was forced to stop. Work on the project resumed in 1962. With major efforts at coordination by all sectors and regions and more than 4 years of hard efforts in the relevant plants, a series of attacks were made on key technical problems including fuel components, technical management, the main pumps, low-pressure seals, water seal equipment and other technologies, materials, equipment and engineering technologies, which made it possible to complete the production reactor in October 1966 and begin a physical startup. Power increases began in December 1966 and it went into normal production operation in 1967.

The preliminary design provided by the Soviet Union for the post-processing plant employed a precipitation process. The technique was complex and involved a long process, required a great deal of equipment, used large amounts of stainless steel, created large amounts of waste liquid, had a low plutonium recovery rate, required large expenditures for operationalization and production operation, and required a long construction period. Foreign countries no longer used this method, having adopted instead an extraction method. For this reason, after an examination of the preliminary design, the Academy of Research and Design in the Second Ministry of Machine Building Industry issued its "Report Concerning Suggestions for Research on Extraction Method Technologies" in January 1959. After the Soviet experts left, research and design for precipitation method technical processes continued, while the Academy worked with the Institute of Atomic Energy, the relevant research institutes in the Chinese Academy of Sciences, Qinghua University and other units to carry out a great deal of survey research, debate and experimentation concerning the feasibility and engineering economy of the extraction method technique. The results showed that the extraction method definitely was more advanced than the precipitation method, and that it had advantages such as fewer investments, lower costs, higher plutonium recovery rates and so on. In May 1964, the Second Ministry of Machine Building Industry decided to adopt the extraction method technology. In December 1964, it also decided to build an intermediate testing plant first at the Jiuquan Integrated Atomic Energy Enterprise. Ground was broken for construction of the experimental plant in May 1965 and it was completed and went into operation in September 1968. Following this, construction of China's first large-scale post-processing plant also got underway in April 1966, and it was completed in April 1970. By this time, China had built rather complete military nuclear fuel cycling systems found in only a few nations in the world.

2. Accelerated construction of the third line.

Construction of the third line was done to meet the needs for war preparedness with strategic arrangements made by the state. In accordance with the spirit of instructions by central authorities and the actual situation in the nuclear industry, the Second Ministry of Machine Building Industry, issued a report on construction in the nuclear industry in third line areas. The special commission of the central authorities agreed with the report of the Second Ministry of Machine Building Industry and decided to begin selecting plant sites in 1964 and to strive to construct a new group of nuclear industry scientific research and production base areas. In March 1964 the Second Ministry of Machine Building Industry convened a special plant site selection work conference,

decided upon the principles of plant selection and assigned a small group to choose the plant sites. Next, in accordance with the spirit of the Central Work Conference and the National Defense Industry Conference, the Second Ministry of Machine Building Industry held a work conference for the special purpose of studying readjustments in strategic deployments, reducing the "first line" and problems in faster construction of the third line. They clarified further the need to fight for time to build the third line and complete it as quickly as possible. At the end of September and the beginning of October 1964, the Second Ministry of Machine Building Industry issued six decisions and one notice that called for all units on the "first line" to combine a conscientious focus on scientific research and production at the present time with a concentration on readjustment of the scale of the "first line" and preparations for construction of the third line. Each unit quickly formulated activity plans for the period from October 1964 to the end of 1965 and began actively organizing classes, selecting and transferring key cadres, collecting data and studying programs. From here, work to build the third line of the nuclear industry began in earnest.

(1) Careful selection of plant sites

The selection of good plant sites was the primary link in the readjustment of strategic deployments and good construction of the third line. The special central commission made several studies of the selection of sites for third line plants in the nuclear industry and leaders in the National Defense Industry Office and the Second Ministry of Machine Building Industry went on-site for inspections. In addition, leading comrades of the central authorities made personal inquiries and even went to examine the terrain of some of the new plant sites.

The site selection work began during the first part of March 1964, when the Second Ministry of Machine Building Industry organized three plant site selection groups with a total of more than 70 people that spent nearly a year under unified leadership by the National Defense Industry Office and travelled several tens of thousands of li, visiting 71 counties and 234 sites. When they arrived at a site, they immediately began collecting the relevant data, including that concerning terrain and geomorphology, hydrogeology, air temperature, humidity, seismic conditions, the local population, agricultural production and motive power, supplies and other subjects, developing their work scientifically according to scientific plant site selection procedures. On the basis of preliminary sites chosen for the plants, the main leaders from the Second Ministry of Machine Building Industry visited the site for re-inspection. Finally, in May 1965, the central special committee, discussed and approved in principle the site selection and construction program for the first project and decided upon the deployment of each third line unit in the nuclear industry. Afterwards, problems of high water temperatures and long water lines discovered during the construction process at some of the plants made it hard to satisfy technical requirements, and the terrain was insufficiently concealed, so readjustments were necessary. On 6 November 1965, Deng Xiaoping and Bo Yibo, accompanied by the relevant local responsible persons, made a personal inspection of a new plant site. Deng Xiaoping felt after the inspection that the new site was a good one. Later, with approval by Zhou Enlai, it received formal approval from the central special commission and the plant was constructed at this site.

At some of the third line plants where the original plans involved tunnel construction, drilling the tunnels proved to be very difficult during construction and involved long construction schedules, so they could not meet the required progress in plant construction. It was decided to choose new plant sites and construction was shifted to the new sites reporting to and receiving approval from Premier Zhou Enlai.

(2) Good construction programs

The third line projects were built to change strategic deployments, so all were considered war preparedness projects that had to be constructed as quickly as possible. In accordance with the principles of the central authorities concerning third line construction, the Second Ministry of Machine Building Industry made decisions concerning the technical designs of the new plants, the scale of production, production deployments, plant site selections, arrangements for production projects and living projects and so on. These decisions played a strong role in accelerating progress in the projects. Some of the decisions, however over-emphasized the need for location near mountains, dispersal and concealment, which caused several problems.

To absorb experiences from construction in "first line" projects and provide good construction programs for third line units, the Second Ministry of Machine Building Industry made a decision concerning conscientious summarization of the experiences from construction of the "first line" projects in October 1964, and called on the main leaders in each of the units to take responsibility for organizing participation by personnel in all fields to make summaries in the eight areas of primary technical processes, equipment and instruments, public health protection standards, auxiliary shop standards and scale, as well as ventilation, moisture-proofing, waste water processing, raw materials transport, staffing, organization and management of capital construction, and service facilities. On this basis, they proposed construction programs and revised opinions concerning each of the third line plants. According to statistics, besides rather substantial changes in production line organization in the new projects, they also adopted more than 470 rather important and effective technical improvements and reforms that increased the safety and reliability of production and transportation, leading to increased rationality in technical processes and easier operation, and some of them attained advanced levels.

(3) Production of all the equipment and instruments in China

To build an independent nuclear industry, China began to develop nuclear equipment and instruments on a large scale as early as the beginning of the 1960's. In February 1965, the central special committee decided to develop third line construction of the nuclear industry in a comprehensive way and to make full arrangements for the development of the various types of important equipment and instruments that were required. In production arrangements, they adopted a method that integrated building of new equipment and instrument manufacturing plants for the third line with consolidation and full utilization of old plants, and they made full use of the potential in existing plants to make products as quickly as possible and create new production capacity in the third line. Decisions were made concerning the departments responsible for developing some key equipment and instruments, and they also required that the quality of the domestically produced equipment and instruments could not be below international standards.

During the development process, each unit employed the requirements by the central special committee and treated the equipment, instruments and devices needed for construction of the third line of the nuclear industry as key state projects for preferential arrangements. As a result, whether one speaks of equipment, instruments and devices that were newly developed in China or copied, all of the demands from construction units were satisfied in progress, quality, performance and other areas, and the quality and performance of some of them attained advanced international levels.

(4) Seizing the time, striving for progress

The Second Ministry of Machine Building Industry adopted several measures to complete a group of third line base areas as quickly as possible. In the spring of 1965 they established a special Nuclear Industry Third Line Construction Headquarters with participation by the relevant leaders from third line regions. Deputy Ministers Liu Qisheng [0491 3217 3932] and Niu Shushen [3662 2579 3947] of the Second Ministry of Machine Building Industry in turn served as general directors, while Chen Yimin [7115 0001 3046], Bureau Director of the National Defense Industry, Bureau Chiefs Chang Zhangtao [7022 1728 3447] and Wen Gongyuan [2429 0501 0337] in the Second Ministry of Machine Building Industry and others served as deputy general directors. They unified leadership over capital construction, scientific research, production and design work in each of the units and quickly solved problems as they appeared. A unified plant construction headquarters was organized from the design, production and construction units at each of the building sites to coordinate and handle relationships between all sides and quickly solve problems in work.

In April 1965, the first group of several hundred people participating in third line construction in the production and design units in the Second Ministry of Machine Building Industry began to enter the third line. Afterwards, a large construction force totalling several tens of thousands of people from fields including earthworks, installation, geological prospecting, machine processing and so on were transferred to the third line.

To deal with problems of materials and equipment shortages, after speaking at a third line construction meeting, Li Fuchun [2621 1381 2504] and Nie Rongzhen [5119 2837 5271] provided assistance in solving the problems. Li Fuchun also approved the establishment of purchasing points for three types of materials in Shanghai and Tianjin and solved problems with materials channels.

To accelerate progress in project construction, Su Yu [4725 5940], member of the CPC Central Committee Military Commission Standing Committee and State Planning Commission Director Yu Qiuli [0151 4428 6849] convened a meeting of leaders from the railway, hydropower, communications, telecommunications, construction and other ministries and commissions and transmitted the joint instructions of the CPC Central Committee, State Council and Central Military Commission concerning the construction of third line nuclear industry facilities, and they combined the Earthworks and Installation Company and the People's Liberation Army Corps of Engineers as well as local construction units to launch a mass campaign to attack construction. They built special railway lines and several hundred kilometers of highways, installed over 1,000 kilometers of communications lines and carried out a large amount of measurements and the corresponding geological prospecting work to make a contribution to construction of the third line of China's nuclear industry.

At the beginning of the 1970's, the third line projects in the nuclear industry were completed and went into operation. Third line construction changed the strategic deployment of the nuclear industry and expanded the production capacity of the nuclear industry, improved technical levels in the nuclear industry and reinforced national defense forces. Practice proved that the decision on third line construction in the nuclear industry was a correct one and that construction of each of the projects basically was successful. The main problems in third lineconstruction were the influences of "left" ideology and restricted levels of knowledge, excessive emphasis on locating the plant sites near mountains and the need for decentralized deployments, and low standards for construction of living facilities, all of which created certain forms of irrationality in production deployments and inconveniences in work and life. This was especially true of the 1970 Plan for the National Defense Industry and the effects of high standards. In addition, a group of later projects were undertaken blindly, which made later readjustments difficult and affected the economic benefits of construction.

Chapter 8: Separation of Uranium Isotopes: Section l. Overview [pp 166-167]

[Text] Uranium is a naturally occurring radioactive element composed of the two primary isotopes of U-235 and U-238. Of the two, U-235 is capable of spontaneous fission, and it is the fissionable fuel that we need. Its abundance in natural uranium, however, is only 0.714 percent. The remaining 99-plus percent of U-238 can be converted to a fissionable fuel only after irradiation by neutrons. Although natural uranium contains only a very small proportion of fissionable fuel, a sustained reaction is possible under certain conditions, so it can be used as a nuclear fuel. However, because of the larger amount of charge required for a reactor that burns natural uranium and its large bulk, as well as technical, economic, and other factors, under most conditions reactors used for power and research utilize "enriched uranium" that contains more U-235. Moreover, the charge provided for use in the atomic bomb required a U-235 concentration in excess of 90 percent. For this reason, separation of the uranium isotopes is necessary to collect the U-235.

There are several methods for the separation of uranium isotopes. The gaseous diffusion method, the centrifuge method, and the spray separation method are of greatest significance for industrial use. The others, like the laser separation method, the chemical separation method and so on belong to the experimental stage. The gaseous diffusion method is the most technically mature and it was the first used for production on an industrial scale. China's uranium isotope separation plants also adopted this methd first.

The basic principle involved in using the gaseous diffusion method for separation of uranium isotopes is that it uses a mixture of two different types of gases and the characteristics of different average velocities of molecules of two different qualities under conditions of equilibrium in thermal motion to allow the uranium hexafluoride gas containing the two isotopes to pass through a specially made separation membrane with many holes and diffuse. The uranium hexafluoride gas molecules containing U-235 are lighter, move at a greater velocity andhave a higher probability of passing through the separation membrane, so they accumulate on one side after passing through it. In contrast, the molecules of uranium hexafluoride containing U-238 are heavier, move at a lesser velocity and have a lower probability of passing through the membrane, so they accumulate on the other side of it, which causes the two isotopes to separate. However, the separation effects created by passing through one separation component are extremely small, so many separation components must be linked together to form a cascaded device that raises separation efficiency. During production at an industrial scale, the cascaded device is composed of several thousand diffusers. By the 1980's, only a few countries, including the United States, the Soviet Union, England, France, and China, had completed gaseous diffusion plants.

Construction of China's gaseous diffusion method uranium isotope separation plant—the Lanzhou Uranium Enrichment Plant—was begun during the late 1950's with assistance from the Soviet Union. After July 1960, when the Soviet Union cut off its aid, China relied on its own efforts to complete it and put it into operation in July 1964. At the beginning of the 1970's, China expanded its enriched uranium production capacity. In the late 1970's, a new type of diffuser designed and developed in China completed fixed testing under specified working conditions and passed a plant operation inspection and state-level examination, providing important facilities for the production of nuclear fuel within China. From the end of the 1950's to the beginning of the 1980's, China developed several types of separation membranes for use in production. At the same time, a scientific research and production staff for uranium isotope separation with a substantial level was trained. They not only attained a comprehensive understanding of gaseous diffusion method technologies but also made progress in the area of centrifuge development and also undertook research on laser separation technologies and chemical separation technologies. This was especially true of the successes already attained in experiments concerning the principles of laser separation of uranium isotopes.

Section 2. Construction of China's First Gaseous Diffusion Plant [pp 168-178]

[Text] l. Selection of a plant site, determination of a plant construction program

In accordance with the relevant agreements between China and the Soviet Union, the USSR supplied China with assistance in gaseous diffusion technologies. Not long after the agreements were signed, an eight-member plant site selection committee for the uranium enrichment plant was set up headed by Liu Baoqing [0491 1405 1987]. Between 29 October 1956 and 15 January 1957, the plant site selection committee surveyed the natural conditions and economic and technical factors of 11 plant sites in Henan, Shaanxi, Gansu, and Qinghai provinces. After comprehensive analysis, it was felt that a site chosen for an aircraft plant in the suburbs of Lanzhou City would be most suited to construction of a gaseous diffusion plant. In February 1957, the site selection committee issued its site selection report. At the time, however, preparations for construction of the aircraft plant had been underway for 2 years and a lot of preparatory work to build the plant had been done. In consideration of the urgent need for development of the nuclear industry, the Second Ministry of Machine Building Industry and the Third Ministry of Machine Building Industry agreed after consultations and reported to the Central Military Committee for approval to transfer the plant site to the gaseous diffusion plant. Arrangements for turning over the plant site were made on 29 September 1957 and work got underway with urgency to build the gaseous diffusion plant.

On 15 October 1957, the Second Ministry of Machine Building Industry approved the design tasks for plant construction. In the winter of 1957, a plant construction preparation office was established, headed by Wang Jiefu [3769 0094 4395]. Next, transfers began to assemble construction staffs for design, construction, installation, production and other preparatory work. In the agreements, the Soviet Union assumed primary responsibility for the preliminary design of the plant. In January 1958, the Second Ministry of Machine Building Industry assigned Wang Zhongfan [3769 0022 5603] to lead a special group to visit Leningrad in the USSR to participate in the preliminary design with their Soviet counterparts. At the beginning of May 1958, Soviet design experts and Chinese personnel studying in Leningrad went to Beijing. On 30 May 1958, Minister Song Renqiong convened a preliminary design examination and approval conference for the plant, attended also by Soviet experts. During the examination process, a large number of revised opinions were offered and consensus was obtained on points of contention through bilateral consultation. In the end, Minister Song Renqiong approved the preliminary design on behalf of the Second Ministry of Machine Building Industry.

2. Fighting for time, going all out to build the project

(1) Comprehensively undertaking the primary and auxiliary projects.

In light of the decision at the time to observe the principle of differential imports, all tasks that China was capable of undertaking were to be the primary responsibility of units within China. The Design Academy of the Second Ministry of Machine Building Industry assumed responsibility for the design for construction of the gaseous diffusion plant. The earthworks projects and equipment installation were the responsibility of the No 101 Company and the No 103 Company, respectively. The upstream and downstream water systems in the area of the plant were assigned by the Construction Engineering Department to the Academy for Drainage Design. The large bridge and electric power grid supply line projects to link the plant areas and the living areas were undertaken by the Ministry of Railways' No 1 Academy of Design, No 1 Prospecting Team and No 1 Bridge Engineering Team, and the Northwest Academy of Electric Power Design in the Ministry of Electric Power, while the Power Transmission and Transformation Project Office in the Gansu Province Electric Power Bureau assumed responsibility for design and construction.

In 1958, a high tide of construction like that throughout China appeared at the uranium enrichment plant. The first generation pioneers in the nuclear industry responded to the motherland's call and within a very short period of time assembled people from all battlefronts in 21 provinces, municipalities and autonomous regions at the construction site. In consideration of the large area covered by the main technical plant building at the gaseous diffusion plant and the long construction period, as well as the large number of auxiliary projects and the need to finish outfitting prior to completion of the technical project, a construction deployment of "first the exterior, next the main body, use the primary to guide the auxiliary and the auxiliary to guarantee the primary for coordinated progress" was decided upon. During the spring of 1958, after completion of preparations for construction, work got underway on the exterior. On 28 May 1958, the Soviet Union informed us that from September 1958 to 1959 some 13 diffusers of various models would be provided. This required that China complete a matchup of the main project and the auxiliary projects and prepare the conditions for installation before the end of 1959, which was a very difficult task. On 39 May 1958, a plant leadership conference held in Beijing to study overall arrangements for speeding up the pace of construction issued the slogan of "hard work for a year and half, combining work with study, completion, and mastery." In July 1958, work got underway fully on the various auxiliary projects and matching facilities in the plant region. Construction of the main technical plant building also began in September 1958. In their efforts to build the project, large numbers of design personnel responsible for its construction and design ate and lived at the work site, working intensively on-site in close coordination to solve problems in construction as they appeared. Chief Engineer Wang Zhongfu [3769 0112 1381] of the Academy of Design became seriously ill, sometimes even spitting blood, but continued to work at the construction site. Deputy Secretary Li Chuncai [2621 2504 2088] of the No 101 Company CPC Committee spared no effort in performance of his duty and gave his own life. Because the production, design, construction and installation units which participated in the construction were organized in an organic fashion with mutual coordination, the night-and-day struggle waged by the broad mass of cadres, engineers, technicians and workers greatly accelerated the pace of project construction. (2) Fighting for a victory in primary facility installation

In June 1959, there were obvious indications that the Soviets would not honor the agreement. After National Day [October 1] in 1959, the leaders of the Second Ministry of Machine Building Industry with primary responsibility for the plant Zhang Pixu [1728 0012 4872] and Wang Jiefu laid their cards on the table and called for a maximum effort to push forward with the main technical plant building and striving to move the primary equipment into the plant according to plan and complete the installation of the main equipment by the end of 1959. The Soviet specialists and responsible persons on the site at the time, however, felt that it basically was impossible to carry out primary equipment installation during 1959. The situation was critical.

In late autumn in the vast northwest, the outdoor temperature dropped suddenly, meaning that little time remained for construction. Under conditions of insufficient time, heavy tasks and great pressure, an on-site

construction headquarters with Wang Zhongfan as the general director was established. Moreover, a prompt decision was made to consolidate the front and concentrate forces on construction of the main technical plant building and assure that the main equipment was installed during 1959.

The on-site headquarters formulated overall plan arrangements and precise project schedules, and they organized and mobilized all employees in construction, installation, design and production departments in joint efforts in an all-out war. They also issued the slogan "everything to install the main equipment, everything stands aside for the main equipment," thereby arousing a high tide in construction of the main technical plant building.

During the first part of December 1959, after an inspection of the main technical plant building by the Soviet specialists, the feeling still was that the beginning of the second year [1960] was the earliest that it could be completed. On 18 December 1959, after a hard battle by all employees, the main technical plant building was finally completed, creating the conditions for installation of the primary equipment. At this time, the Soviet specialists paid a second visit to the site and suggested that the cleanliness of the plant building did not meet specifications, so the primary equipment could not be installed. They shook their heads and said that at least a month and more would be required to complete the work. The leaders of the plant replied with firmness "look again in 3 days and decide!" The plant immediately decided to have Deputy CPC Committee Secretary Liu Zhe [0491 0811] mobilize more than 1,400 people for cleaning. Without regard to their job status or physical strength, the broad mass of cadres and workers vied with each other to get into the plant, dividing it up in sections for cleaning and worked continuously for 24 hours. Besides cleaning every crevice, the equipment base, platform and even the corners of walls and ditches were cleaned. Not a ditch was left uncleaned. They first washed with water, wiped with cloths and finally polished with a white cloth. Before the day dawned, the plant building for installing the primary equipment was gleaming. When the experts arrived at the site for their inspection, they were stunned and could not help saying: "this must be a trick!" They agreed on the spot to speed up the movement of the equipment and production specialists into the plant immediately. At a banquet that evening, the experts asked: "why is it that we estimated that it would take more than a month to complete the work when you were able to finish it in one night?" The plant leader laughed and said: "this is the strength of Marxism-Leninism, Mao Zedong Thought and the Mass Line." They picked up their wine glasses and shouted "Long live Marxism-Leninism and Mao Zedong Thought! Long live the mass line!"

On 27 December 1959, the first group of main equipment was installed at the main technical plant building. The victorious installation of the primary equipment provided the initiative for sustained progress in the project before the Soviet specialists departed and played a decisive role in its completion on schedule.

(3) Studying and digesting diffusion technologies

Importing equipment is not the same as understanding a technology. This is especially true of a sophisticated technology like gaseous diffusion. Not only does it require an enormous cascade, much equipment and long pipelines, but moreover the actuating medium is uranium hexafluoride gas, which is radioactive and highly corrosive, and it places very high demands on a high degree of sealing for a large volume, resistance to corrosion, cleanliness and so on, so the technology is extremely complex. China formerly was a blank, moreover, in the field of nuclear isotope separation and it would be no easy task to gain a full understanding of it in a short period of time. At the time, the S&T personnel at the diffusion plant responded to Chairman Mao Zedong's instruction to "respect our Soviet comrades, be assiduous and open-minded in study, but also be certain to eliminate superstition." They integrated the practice of seriously learning from the Soviet experts but also followed independent thought and study, and their achievements were apparent.

Because the Soviet Union would not accept Chinese apprentices at the diffusion plant, China decided during construction of the diffusion plant to establish a diffusion laboratory in Beijing to serve as a training base area. Ground was broken to build this laboratory on 20 September 1958 at the Institute of Atomic Energy of the Chinese Academy of Sciences in Beijing, and construction of the plant building began on 23 October 1958. The installation of some of the equipment also got underway. Afterwards, groups of Soviet experts came to China for rather comprehensive training of key technical cadres and specialized administrative personnel sent by the diffusion laboratory and the diffusion plant.

The timely completion of the diffusion laboratory not only provided the conditions for opportunities to practice in actual operation of the equipment and trained a large group of technical cadres and specialized administrative personnel to grasp gaseous diffusion technologies for China, but also permitted the training base area to play an important role after the Soviet experts departed, and they did a great deal of work during and after the startup of the first diffusion plant. This was an important decision for assuring that China's first gaseous diffusion plant would be completed and go into operation. Afterwards, the training base area also grew to become a scientific research base area for uranium isotope separation in China.

During the process of plant construction, to combine work and study and to complete and understand it, the broad masses of employees raised a high tide of study toward the Soviet experts. The engineers and technicians at the site worked and studied, doing something and then

studying it. In addition, they also invited specialists to teach classes so that leading cadres understood and grasped key problems, so that special technical personnel could grasp specialized technologies, and so production workers could understand operating techniques. Because everyone studied from the experts with a warm and sincere attitude, friendships were established between the Chinese and Soviet experts, technicians and workers. Some of the Soviet experts also indicated that they definitely wanted to "finish the church."

In the spring of 1960, a "technical revolution and technical innovation movement" arose in China. During the peak of the movement, some people at the diffusion plant removed electrical equipment from the technical plant building for innovation. If this sort of method had continued, the results would have been serious. How should these newly-imported technologies be dealt with during technical innovation? At exactly this time, Chairman Mao Zedong gave a timely instruction: "like a child learning to write, we first of all must draw block characters before we can write script." The timely transmission of this instruction placed study on a healthy track, with very good results. During this stage, 595 key production and technology cadres with a preliminary understanding of diffusion technologies were trained, and they laid the foundation for a rapid transition to reliance on our own efforts to deal with technical questions after the sudden departure of the Soviet experts.

3. Relying on our own efforts, attacking key technical problems

On the morning of 3 August 1960, all of the Soviet experts assembled at the site to return to the USSR. The employees at the diffusion plant did not forget the assistance and support they had received from the Soviet experts and accompanied them warmly one by one to the Lanzhou train station or airport. From this point on, construction at the diffusion plant entered a new stage—the stage of total reliance on the principle of depending on one's own efforts.

(1) The situations and problems we faced

After the Soviet experts left, the feeling in international circles at the time was that China had entered a state of vacuum in nuclear technology. Some even predicted that "China will not have the atomic bomb for 20 years." Others even said that "this is a devastating blow for China" and "two years from now China will be selling scrap copper and rusty steel." At the time, the primary technical equipment for the diffusion plant had not been fully outfitted, and some important technical data had been carried back to the USSR by the experts or burned. The technicians at the diffusion plant already had studied some of the technologies, but they lacked practical experience and had no place to get it. Pessimism also could be found among a small number of the employees who felt that "the experts have gone, and we cannot deal with the technology"; "capital construction we can handle, but not production"; "auxiliary production we can handle, but not the primary technologies" and so on. This was especially true in light of the dire economic situation throughout China at the time, and some of the employees even began to think of returning home to farm.

Could we defeat our difficulties and rely on our own intellect and strength to build the diffusion plant? The creators of the diffusion industry in China were faced with a serious test.

(2) Determination and confidence

On the afternoon of the day that the Soviet experts departed, the leaders of the plant made arrangements for all items of work after the experts had departed to assure normal progress in construction of the plant. Afterwards, the Second Ministry of Machine Building Industry issued its instructions on 9 August 1960 to "struggle for the principle of complete reliance on one's own efforts in ministry affairs" to deal with the various ideological and intellectual problems that had burst out among the employees. They discussed the situation and the bright future, and they did education concerning a feeling of glory for the situation, the future and the industry. At the same time, cadres at all levels went to the employee dormitories to see if they were warm or cold and into their cafeterias to ask about their food. When conditions permitted, the living problems of the employees were resolved to the greatest possible extent. The CPC Central Committee also provided preferential treatment for the employees of the diffusion plant in the area of living materials supplies. Gansu Province and Lanzhou City under the most difficult conditions assured coal and electricity supplies for the plant and the needs of employees for edible oils, meat and non-staple goods. The concern of the CPC Central Committee, the instructions of the Second Ministry of Machine Building Industry and the support from the local area warmed the hearts of the employees. It unified the ideology of all of the plant's employees, clarified directions and firmed up their resolution.

On the basis of organizing a "great transition" and unified employee ideologies, the plant undertook "exploration of the exact details" activities in five areas. They explored the details of project quality, the details of employee technical levels, the details of technical information, the details of equipment and materials, and the details of attacks on key problems. During the process of exploring the details of project quality, Deputy Minister Yuan Chenglong [5913 2052 7127] of the Second Ministry of Machine Building Industry began staying at the plant for a long period in January 1961 to provide direct leadership of survey research work focused on quality and to organize over 20 special groups to carry out a comprehensive survey of the situation in construction and installation of the primary technology and auxiliary systems, and they discovered 1,395 problems. During

the survey, they explored the details and determined that the design of the primary technology for this plant was rational, that the quality of construction of the main structure was good, and that primary equipment was complete. The Soviets, however, had not provided some important components, so much effort was expended in trial development and assembly. To achieve this, the State Council gave the related ministerial committees responsibility for setting up special organs and organizing a major cooperative effort throughout China to develop special matching equipment, which created the conditions necessary for continued installations and attacks on key problems in startup at the diffusion plant.

(3) Startup tests for the main equipment

After the Soviet experts left, the equipment assembly and installation was completed after more than a year of hard work. Exploration of the details of quality permitted us to clarify and understand various quality problems, and full preparations also were made in ideology, organization, materials, technology and other areas. At the end of 1961, startup experiments for 10 pieces of equipment of different models began.

Uranium hexafluoride, the actuating medium in the diffusion plant, is radioactive, and it is corrosive after coming into contact with water. This places extremely strict requirements on the vacuum seals of the diffusion equipment. In the scientific laboratory, a vacuum seal is nothing difficult, but maintaining a vacuum seal in a diffuser with such a large volume, kilometers of pipes and more than 10,000 joints was not an easy task. For this reason, the plant organized a special vacuum work staff. They replaced more than 5,000 large and small valves, readjusted several hundred cracks in the primary equipment and eliminated more than 10,000 leaks. After arduous efforts, they finally attained the operational requirements and even explored some experiences regarding a set of vacuum seals that created the conditions for further experimentation.

The experiments embodied the spirit of "writing block characters first" and work progressed step by step. To assure the success of the experiments, a pattern of "small equipment first and large equipment later, single models of equipment first and combined operation of multiple units of the same model later, small loads first and larger loads later, mutual examination and approval of foreign materials first and Chinese produced materials later" was adopted and things progressed smoothly. During the attacks on key problems, emphasis was placed on not dealing with things not understood, compiling an experimental outline and concrete experimental program before testing, calling for ideas from all sides and full preparations. Theoretical calculation personnel calculated more than 100 static operation programs and several thousand non-static operation programs. They also stressed the need for drills prior to major tests and activities after operational practices to prevent mistakes.

Fluoridization processing was a key procedure prior to startup of the equipment. If the processing was not done well, the separation membrane would not satisfy permeability requirements, and an excessive speed of fluoride filling could burn up the separation membranes. Because strict training of the relevant personnel was done in advance, everything was done with meticulous care during actual operation and strictly in accordance with regulations. As a result, not a single separation membrane was damaged during the fluoride processing of several thousand pieces of equipment.

The experiments led to successes in trial fluoridization processing and startup operation of a representative portion of the various types of diffusers. They grasped separation coefficients, losses due to corrosion, static characteristic roots and other important parameters. They explored the laws of declining permeability in separation membranes. They not only gained extremely valuable practical experience in diffuser startup but also discovered and eliminated many equipment faults to clear the path for fluoridization processing, startup and production of the diffusers in groups.

The engineers and technicians played extremely important roles during the attacks on key technical problems. The members of the leadership group for attacks on key technical problems at the plant, including Chief Engineer Zheng Liuyang [6774 3177 7122], Deputy Chief Engineer Liu Baoqing, senior technicians, senior power engineers, senior instrument engineers, technical inspection offices, primary technology shops, the related shops and others, met together frequently to solve technical problems as they arose. At each crucial point, many people moved to eat and live at the site for joint attacks on key problems with the masses of technicians and workers. During those days, whether one is speaking of leaders at all levels, special administrative cadres, or technicians and production workers, all gave their utmost effort to this enormously difficult activity.

4. Startup in groups, successful operation on the first try

By November 1962, assembly and installation of all of the main auxiliary projects at the diffusion plant were completed. On 8 December 1962, fluoridization processing of the equipment in groups formally got underway and startup of the equipment in groups also was to begin. Construction of the diffusion plant entered a decisive stage. The "two-year plan" proposed by the Second Ministry of Machine Building Industry at this time calling for efforts to explode the first atomic bomb by 1964 had been approved by the central authorities. The first 14 months were the decisive 14 months in the battle, and required that the diffusion plant produce highly enriched uranium products ahead of schedule. The startup program based on the Soviet design, however, would not have made it possible to produce the products ahead of schedule. Under the direct leadership of Liu Baoqing,

Wang Chengxiao [3769 2052 1321] and others, theoretical calculation personnel recalculated a startup program. After several revisions, they finally proposed a new program for startup of all of the equipment in nine groups and production of products in five groups one-half year ahead of schedule from the original plan. A technical discussion group composed of Chief Bureau Director Bai Wenzhi [4101 2429 3112], specialists Wu Zhengkai [0702 1767 6963], Wang Chengshu [3769 2110 2579], Qian Gaoyun [6929 4108 7301] and others went to the plant to listen to reports. After rebate, it was felt that the program basically was rational, and it received quick approval from the Second Ministry of Machine Building Industry.

Before the startup of the equipment, many "worrisome" problems remained. The Diffusion Laboratory of the Institute of Atomic Energy worked inclose coordination with the plant and carried out a large amount of theoretical, experimental and technical research to prepare a persuasive program. For example, the purification stages for the purification of the light impurities used at the refined material end did not even meet the number required in the original design, and there were doubts. Because it concerned the question of whether or not it would be possible to have a light impurity content below the limit for the specified product, it had to be understood clearly. To achieve this purpose, the diffusion laboratory not only made theoretical calculations but also utilized a small machine short cascade for technical experimentation to remove the doubts. In addition, a large number of parameters were derived concerning the effects of aspects in the startup and adjustment of the diffusion cascade, including startup patterns, side linkages and branches in the equipment and equipment shutdown on the technical return loops. This work played a positive role in the successful startup of the equipment.

To assure the success of startup by groups, strict examinations were made of the various technical parameters involved in fluoridization processing prior to startup. Tests were run on the matching equipment stations. Precision analyses were made of the raw uranium hexafluoride material and the standard samples needed for startup of each group were prepared. The specifications were checked for all instruments and automatic control systems in the primary technical workshops. All operational regulations underwent examination, approval, promulgation and implementation. Strict tests were given to all operating personnel and managerial cadres, and those who did not meet specifications were not allowed to take their positions. The result was that every item of preparatory work for startup of the equipment in groups attained high standards and strict requirements. Moreover, the relevant personnel also made a conscientious summarization of the startup and operational situations for the first four groups of equipment. The result showed that the "Temporary Operational Regulations for the Primary Technical Equipment" they had compiled were feasible. All of this led to full preparation for the startup of the fifth group of equipment.

In December 1963, the fifth group of equipment was started up. This was the key to the diffusion plant's ability to have its products conform to specifications in advance of schedule. On the day of startup, all of the plant's leaders came in advance to the workshop and after making strict checks of all items of preparatory work, startup began. The U-235 concentration in the technical cascade rose continually. Before startup, the Diffusion Laboratory in the Institute of Atomic Energy calculated temporal change curves for the U-235 concentration in the cascades during the processes of startup, program change-over, equipment side linkage and so on, and the measured data during the early part of the startup of the fifth group conformed quite well with the curves. This strengthened their confidence in being able to obtain the specified product.

The calculated program indicated that product concentration should reach 90 percent on 14 January 1964. At 11:05 am, the valves were opened slowly on the product container and the highly enriched U-235 containing enormous energy flowed into the container. After careful analysis, the quality of all of the product met ministerial standards and the diffusion plant achieved a major victory in successful operation on the first try. When this good news spread through the plant, people were filled with tears and countless pairs of hard working hands shook vigorously, unwilling to be separated.

On 15 January 1964, the Second Ministry of Machine Building Industry sent a congratulatory telegram saying that "this is the first important milestone in the development of our ministry's activities, and it has created the necessary conditions for success in our ministry's affairs." On 18 January, Chairman Mao Zedong wrote his approval on the report submitted to the CPC Central Committee by the Second Ministry of Machine Building Industry: "very good."

The attainment of highly enriched uranium products ahead of schedule not only answered the question of whether completion and startup were possible, but also gained extremely valuable time for achievement of the "2-year plan."

The central authorities were extremely concerned with the construction of China's first gaseous diffusion plant. Deng Xiaoping, Peng Zhen, Peng Dehuai, Nie Rongzhen and other leaders visited the plant. The central special commission aided in solving many important questions during construction of the project. Construction of China's first gaseous diffusion plant also was supported by forces throughout China. Every region and enterprise actively answered Chairman Mao Zedong's call to "make great efforts at cooperation, do this work well." They not only transferred large numbers of personnel to assist in construction of the diffusion plant but also actively cooperated in training production and technical personnel. There were 22 cities and 81 industrial units that provided more than 400,000 instruments, devices and components of 832 types. There were 237 plants in

44 large and medium sized cities which gave a green light to preferential processing of 433 types of electrical devices, instruments and standard equipment totalling more than 14,000 pieces. Many units also sent technicians to the plant to aid in solving key technical problems. These included the Chinese Academy of Science's Shanghai Institute of Organics, the Institute of Metallurgy, Shanghai's Electrical Machinery Plant and Guanghua Instrument Plant, the Beijing Academy of Petroleum Sciences, the No 621 Plant, the Harbin Electrical Equipment Plant, the Gas Turbine Plant, the Wafangdian Bearing Plant, the Luoyang Bearing Plant, the Xi'an Instrument Plant and others. The construction and operationalization of the gaseous diffusion plant was a song of triumph for the large national cooperative effort!

Section 3. Development of Gaseous Diffusion Technologies [pp 178-182]

[Text] On 6 April 1964, not long after the diffusion plant went into operation, Minister Liu Jie of the Second Ministry of Machine Building Industry made a further demand on the employees of the diffusion plant to "have a thorough grasp of the details." In accordance with this demand and after 2 years of effort in 1964 and 1965, the plant perfected a production assignment responsibility system, reinforced equipment safeguards, carried out a successful experimental overhaul on the diffusers, developed scientific research and innovation experiments, and summarized mainly preventive experiences in ensuring safe production. A qualitative change swept over the plant in ideology, management, technology and working styles. The products met specifications 100 percent and all economic and technical indices surpassed levels in the original plans. Gaseous diffusion technology then began to enter a period of "writing in script."

1. Developing technical innovation, exploiting production potential

After a great deal of effort at the gaseous diffusion plant to achieve a comprehensive understanding of diffusion technologies, they also exploited potential, innovated and transformed and achieved obvious successes in higher flow rates in the primary equipment, separation capacity and cascade efficiency.

(1) Improving flow rates in the primary equipment.

In August 1975, the diffusion plant proposed a program for innovation in the main equipment to raise main equipment flow rates and increase output during the Fifth 5-Year Plan. This was the "Program for Increased Output of Primary Products During the Fifth 5-Year Plan." It involved innovation and transformation of the main components and associated auxiliary systems for the main equipment rotors, electrical machinery, bearings, technical transformers and specialized instruments so that they could continue sustained and safe operation after flow rates in the main equipment were increased.

From 11 to 21 January 1976, the Second Ministry of Machine Building Industry held a technical discussion meeting at the diffusion plant. The meeting discussed questions put forward by Deputy Minister Li Jue [2621 6030]: "What are the potential parameters of the main equipment?" "What is the potential under increased load conditions?" "What criticality problems are there?" Deputy Plant Manager Jiang Xinxiong [5592 1800 7160] reported on the large amount of work done concerning the "three whats" and the results obtained. After comprehensive discussion, the personnel at the meeting agreed that the "Program for Increased Output of Primary Products During the Fifth 5-Year Plan" was feasible. The Second Ministry of Machine Building Industry gave its formal approval on 5 May 1976.

Through the initiative and efforts of the employees of the diffusion plant, the entire plan for innovation was completed on schedule. The flow rate of the main equipment increased by 35 to 47 percent and the goals for increased output proposed by the ministry for 1978 were achieved 2 years ahead of schedule.

(2) Increasing separation capacity.

Beginning in 1975, the diffusion plant remade some of the diffuser separation membranes to increase the rationality of the cascade structure. They effectively increased separation efficiency, increased the separation capacity of the machinery and raised production capacity by 26 percent over the original type of machinery.

In 1980, the diffusion plant again formulated development plans for cascade improvements during the Sixth 5-Year Plan. To ensure that this plan was implemented, the separation membrane production plant reinforced its scientific research work. This lead to an enormous breakthrough in separation membrane technologies and provided timely new separation membranes with a high separation efficiency, corrosion and vibration resistance and long, useful lives. On the basis of changes in the designs of the diffusion separators and excellent results in technical experiments on single machines, the technicians also began innovations and transformations in the separators. This led to a substantial increase in separation efficiency before the innovation and there also were obvious improvements in the operational conditions of the technical cascades.

(3) Raising cascade efficiency

The technical cascade at the diffusion plant is composed of many diffusers of different types, so increased cascade efficiency is the most effective method for lowering product costs.

As electronic computers have come into broader use, they have created excellent conditions for the selection of optimum cascade programs. Under the leadership of Liu Guangjun [0491 1639 0971], theoretical calculation personnel integrated closely with production realities

and did a great deal of work which led to greater rationality in the cascade structure and a corresponding improvement in cascade efficiency. By 1985, the actual cascade efficiency of the gaseous diffusion plant was much higher than at the time of startup and operationalization, and it approximated international levels. Starting in 1981, Chinese low-concentration uranium products entered international markets and the quality of the products was well received. In 1982, the enriched uranium product series received a "silver award" from the state. The production capacity of China's first gaseous diffusion plant has increased many-fold, while the costs of the innovations and modifications were less than 10 percent of the investment to build the plant.

2. Developing diffusion technologies, developing new types of diffusers

In the early 1960's, China's machine industry completed its task of trial manufacture of diffusers, and a great deal of rather mature experience gained in design, manufacture, installation, operation and other areas prepared the conditions for design and development of new large-scale diffusers.

To expand the production capacity of the diffusion plant, the Second Ministry of Machine Building Industry decided in April 1964 to establish the Academy of Physics and Chemical Engineering in the Second Ministry of Machine Building Industry on the basis of the Diffusion Laboratory of the Institute of Atomic Energy. One of its tasks was to assume responsibility for research and design work related to new types of diffusers.

Generally speaking, the development of a new type of diffuser should have the benefits of improved economic results. When deciding upon the separation capacity of a diffuser, however, comprehensive consideration must be taken of such aspects as China's need for nuclear fuels, technical levels in domestic industries and so on. The key to development of the new type of diffuser was the design of a compressor. With substantial assistance from the Third Ministry of Machine Building Industry, the Institute of Physical and Chemical Engineering of the Second Ministry of Machine Building Industry produced the first group of compressor design blueprints at the end of 1964. The overall functions and overall structural program for the new diffusers were decided upon at the end of 1964, and the preliminary design requirements for the corresponding components also were proposed.

In 1965, the new diffusers entered the trial manufacture stage. The first blueprints for the overall design of the single diffusers and each of the components were completed between the beginning of 1965 and the beginning of 1966. In April 1966, Lai Jian [6351 1017], Deputy Bureau Chief of the State Council National Defense Industry Office, chaired a "New Diffuser Design Examination Meeting" held in Beijing and approved the program to develop these diffusers.

The trial manufacture of the first single prototype of the new diffusers was carried out primarily by the Academy of Physical and Chemical Engineering in conjunction with Shanghai's Xianfeng Electric Machinery Plant, the Suzhou Valve Plant and the Wuhan Boiler Plant. Trial manufacturing got underway in 1966, but the effects of the "Great Cultural Revolution" meant that the testing station was not completed until 1968 and the new diffuser was put on display. At the same time, the Second Ministry of Machine Building Industry and the First Ministry of Machine Building Industry studied problems with fixed site production of the new diffusers and decided to make the Dongfeng Electrical Machinery Plant in Leshan, Sichuan Province and the Shanghai Electrical Machinery Plant the final assembly plants for the compressors, while the Chongqing Hydraulic Turbine Plant, Shanghai's Dianfeng Electrical Machinery Plant, Gas Turbine Plant and Boiler Plant and the Zhengzhou Cable Plant assumed responsibility for some of the components. The Suzhou Valve Plant, the Shenyang High and Medium Pressure Valve Plant, the Pingdingshan Valve Plant, the Wuhan Boiler Plant and others assumed responsibility for production of the regulators, valves, pipes and other components for the compressors.

In February 1969, the State Council National Defense Industry Office decided to establish a "joint leadership group for development of new diffuser's" under the responsibility of Bureau Chief Zhang Shunan [1728 2885 0589] of the First Ministry of Machine Building Industry and Bureau Chief Jiang Tao [1203 2447] of the Second Ministry of Machine Building Industry, and they established a full-time office. During this period, Deputy Chief Engineer Qu Zhiqian [1448 2535 3383] of the Equipment Manufacturing Bureau in the Second Ministry of Machine Building Industry and others did a great deal of organizational and coordination work. At the same time, an integrated group composed of the institute, the academy of design and the diffusion plant was established within the Second Ministry of Machine Building Industry to assume responsibility for coordinating work on major technical questions. With primary support by the joint leadership group, new progress was made in the development of the new type of diffusers. Testing of single units of the new diffusers began in July 1970. Next, in February 1972, the first trial equipment set was started up for operation. In October of 1972 and in November 1973, all of the experimental cascade equipment went into operation.

The process of developing the new diffusers was a continual process of revealed problems and solved problems. Formal testing of single units began in July 1970, and the final design had been developed by December

1979. Over the 9-year period, more than 100 major technical problems were revealed. Under the leadership of Deputy Minister Li Jue of the Second Ministry of Machine Building Industry and related specialists like Shen Baoquan [3088 0202 0356] and others, the scientific research personnel fought night and day to solve problems so that the new type of diffusers attained all of the technical indices under the specified conditions.

To further exploit the potential of the new diffusers, tests of the improved diffusers were carried out in March 1979 at the Fluid Experiment Station and satisfying results were obtained. The separation capacity of a single unit increased by 33 percent and new breakthroughs were made in development work. The primary functional parameters of the new diffusers now conformed to design indices and utilization requirements at the plant. The primary associated products and the main raw materials could be based on Chinese sources, so the technical conditions were present for complete design blueprints and production examination and acceptance, and each of the manufacturing plants had a basic grasp of its technologies and equipment. In December 1979, the Ministry of Machine Building Industry and the Second Ministry of Machine Building Industry convened a joint "conference on finalized designs for new diffusers" in Beijing and received diffusion plant testing and verification and national level agreement. This important achievement was made through the joint cooperation of 13 provinces and municipalities throughout China as well as more than 100 units under the First Ministry of Machine Building Industry, the Ministry of Metallurgical Industry, the Ministry of Petroleum Industry, the Ministry of Light Industry, the State Construction Materials Bureau, the State Materials Bureau, and other organs. The development of the new diffusers not only provided important facilities for the production of nuclear fuel within China but also provided large amounts of data of reference value for the diffusion plant and pushed diffusion technologies to new heights.

Section 4. Research and Development of Diffusion Separation Membranes [pp 182-184]

[Text] Separation membranes are the core components of gaseous diffusers. The performance of the separation membranes has very considerable effects on the advanced qualities and economy of the diffusion plant.

As for the structure of the separation membranes, they can be divided into single layer membranes and multilayer membranes. They also can be divided on the basis of their material qualities into metallic separation membranes and non-metallic separation membranes. Because uranium hexafluoride has strongly corrosive effects on the materials and can form dangerous fluorides, they require the selection of high purity, corrosion-resistant materials before the specified separation efficiency can be maintained over long periods. China now has a grasp of several types of techniques for manufacturing separation membranes.

1. Reliance on our own efforts to develop separation membranes

Separation membranes are the key components in a diffuser. To sustain production in the diffusion plant, the Second Ministry of Machine Building Industry divided up the work, with Qian Sanqiang [6929 0005 1730] organizing forces to carry out readjusted research and theoretical exploration work for separation membranes. Afterwards, the National Defense Industry Office also transferred together scientific research forces from all members to begin development. After a great deal of coordination and arduous work by vast numbers of S&T personnel in the Chinese Academy of Sciences, the Second Ministry of Machine Building Industry, the Ministry of Metallurgical Industry, the Ministry of Textiles, Shanghai's Fudan University and other research units, in only 2 years' time they had overcome this sophisticated technology and developed China's first-generation separation membranes (A and B type separation membranes) that were installed in the diffusers to create the conditions for stable production at the diffusion plant.

2. Construction of the separation membrane production plant

In 1963, on the basis of experimental research by the Second Ministry of Machine Building Industry and the Ministry of Metallurgical Industry and semi-industrial experiments, preparations for the design of industrial separation membrane production plants began. In 1964, the central special commission decided to build a separation membrane plant. Minister Lu Dong [0712 2639] of the Second Ministry of Machine Building Industry personally went to select the site and a decision on the plant site was made at the end of 1964. The State Planning Commission included the separation membrane manufacturing plant among key national projects that must be completed. The Headquarters of the General Staff of the Chinese People's Liberation Army transferred the Railway Engineer Corp to the site to join the Ministry of Metallurgical Industry in construction. It took only 22 months from the time the foundation was laid in April 1965 to January 1967, when the first batch of products meeting specifications was produced, so an excellent achievement of successful operationalization on the first try was attained.

3. The development of separation membrane technologies

Scientific research work on separation membranes went on even while the plant was being built. If the diffusion plant wished to exploit potential for transformation during the Fifth 5-Year Plan and to improve cascade planning during the Sixth 5-Year Plan, the key was improved separation membrane performance and development of new types of separation membranes. After much hard work by scientific research personnel, major

breakthroughs were made in technologies and the structure of the separation membranes was changed for successful development of types C and D separation membranes, which had better quality and characteristics. In addition, production costs were decreased substantially, and the type D separation membrane was extended quickly into production. In 1976, to improve the physical and chemical functions of the separation membranes and to increase separation efficiency, intensive survey research served as the foundation for improvements in raw materials production techniques and changes in the shape of the structural materials in the separation membranes. This provided new types of separation membranes for the diffusion plant that had high separation efficiency, were corrosion-resistant, vibration-resistant and had long, useful lives. Through production practice, the various technical indices of the separation membranes reached rather high levels. Continual renewal of the separation membranes not only made a positive contribution to improvement of overall economic results at the diffusion plant but also created extremely favorable conditions for the development of large-scale diffusers.

During research and development on separation membranes, because we adhered to the principles of placing scientific research in the front ranks, closely integrating scientific research and production, paying attention to renewal and replacement of product varieties and exploiting potential for transformation in production lines, the technology advanced quickly and the achievements were apparent. The scientific research achievements for separation membranes received an "award for a major contribution to science and technology" at the National Science Conference in 1978. In addition, the National Defense Science and Industry Commission and the State Science Commission awarded first and second place invention awards in 1984.

Chapter 9. Manufacture of Nuclear Fuel Elements: Section 2. Development and Production of Fuel Elements for the Production Reactor [pp 195-197]

[Text] The fuel elements used in China's light water cooled graphite moderated production reactor are metallic rod-shaped elements with a uranium core and an aluminum casing. There is a nickel-plated layer between the core and the casing, forming a metallurgical bond between core and casing to meet the heat transfer requirements of guiding out the heat within the reactor during operation.

1. Development of the elements used for testing

Research on manufacturing technologies for production reactor elements began in 1960, and some work was done shortly thereafter concerning "phosphorus-coated, hot pressed dense alloy" technologies. Because this technology was outdated and backward, it was hard for product quality to satisfy requirements. Technical Engineer Ji Bingxian [6060 4426 6343] and others used data from foreign countries and their own research and practice to transform "phosphorus-coating, hot pressure" into "nickel plating—gas pressure" technology. After this, the development work went into high gear.

As construction progressed at the production reactor, work to develop the elements also advanced quickly. To assure completion of each of the research tasks, the [element] plant organized a Production Reactor Element Mass Campaign Headquarters in May 1964 and formulated plans for a mass campaign. The headquarters called for concentration of forces for breakthroughs in production technologies and working as quickly as possible to make products meeting specifications.

From May to November 1964, the element plant completed research on technologies for refining and casting crude uranium metal. They made preparations for rolled heat processing of the uranium core rods, especially for the installation of the rollers and measurement of air pressure heating furnace temperatures. Transformation of the original workshop design was done on the basis of nickel plating technologies. During this period, the aluminum casings and aluminum caps also were manufactured successfully. During the refining and ingot casting process, "air bubble" and "shrinkage cavity" phenomena appeared on the inside and outside of the uranium ingots and affected the quality of the pure uranium ingots. After a period of exploration and experimentation by a group for attacks on key problems in refining procedures, an understanding was gained gradually concerning the laws of refining and casting and better technical conditions were found.

Trial manufacture of the uranium metal elements began in December 1964. To assure optimum diffusion of the aluminum-nickel-uranium layers, technicians at the Shenyang Institute of Metallurgy and the element plant did several experiments. They discovered the various key factors that affected adhesion and clarified the relationship between the structure and degree of bonding of the diffused layers and the air pressure and temperature. Based on the production equipment situation, they chose technical parameters and produced a group of elements for use in testing. The elements met quality standards in adhesion, geometric dimensions and exterior quality as well as the chemical components, density and crystallinity of the core rods and other areas. At a conference of design, production and user units convened by the Second Ministry of Machine Building Industry in March 1965, the attendees examined the production technologies used for the elements provided for testing. They confirmed their evaluations of the quality of the trial-manufactured elements and also offered some opinions concerning improvement of the quality of the elements and other relevant questions.

2. Large scale production of the elements

Based on the need to make progress in construction of the production reactor, the element production plant had to produce considerable numbers of elements before the end of 1966 to satisfy the needs of reactor startup. This required that the plant shift quickly from small-batch production to production on a large scale.

To deal with this urgent task, the "element mass campaign headquarters" organized the production workshops, Element Research Laboratory, Academy of Design, Shenyang Institute of Metallurgy and other units to participate in attacks on key technical problems. They made comprehensive examinations of crude uranium refining, pure metal rolling and hot processing from April to July 1965. During the examinations, they adhered to the spirit of "strictness in everything" and did not miss a single factor that could have affected production. Through strict examination of the production technologies, tight organization of production management, strict training of operating personnel and vigorous solution of problems that appeared during production, a large amount of work in preparation for production was completed. In September 1965 the Second Ministry of Machine Building Industry convened a Production Reactor Element Manufacturing Technology Summarization Conference. The meeting felt that the preliminary results of testing the elements in the reactor had shown that the quality of the elements could satisfy user requirements, that the existing production technologies basically were stable and that the element plant had the conditions for large scale production.

This technical summarization conference actually was a pre-production technical examination and acceptance conference. After the meeting, the element plant went into large scale production and provided elements according to specifications for startup and operation of the production reactor ahead of schedule.

3. Continued improvements in production technologies

In the manufacturing technologies for uranium metal fuel elements, the technologies involved in the original design for uranium smelting and processing into final form were rather backward. To change this situation, the element plant carried out continual technical transformations after it went into operation that made considerable improvements in the original technologies. For example, the first technology adopted to produce the cores of the natural uranium rod elements was gg-phase rolling and quenched hot rolling technologies. To reduce dust pollution and reduce the intensity of labor, technicians at the element plant and the Shenyang Institute of Metallurgy made a joint study of a new group of ga-phase rolling and gg-phase quenching cold rolling technologies, and they went into formal use in production in 1976.

After the element cores are wrapped in an aluminum casing, a rotary lathe must be used for rotary pressure processing of the end surfaces of the elements to seal them. This process first of all was done annually and involved very intensive labor, but the quality of the rotary pressure could not be guaranteed. In 1972, the plant designed and manufactured a "special semi-automatic end-surface rotary pressure lathe." This lathe used the principle of oil damping to control the speed of all operations and thereby achieved semi-automation of element end-surface rotary pressure. The manufacture of the semi-automatic rotary pressure lathe made lathe adjustment easier and precise control over rotary pressure technology parameters was achieved, which guaranteed rotary pressure quality and greatly reduced labor intensity.

In addition, the element plant also carried out research on a new reduction—refining—forming calcium hot reduction technology. The new technology combined the essentially different reduction and refining procedures, which made it possible to simplify technical procedures, reduce production times and raise production efficiency and product recovery rates. Rather good results were attained during production tests.

Section 4. Development of Fuel Elements for Power Reactors [pp 201-202]

[Text] The development of power reactor fuel elements in China began with the fuel elements for a nuclear submarine power reactor. These elements were successfully developed in 1970 and performed quite well during operational testing. Afterwards, to adapt to the need for nuclear power in development of the national economy, development of fuel elements for nuclear power reactor stations got underway in 1973 and construction of a production line for this type of element began in 1975.

l. Development and production of fuel elements for nuclear submarine power reactors

As early as August 1958, when central authorities decided to develop a nuclear submarine, the Beijing Institute of Atomic Energy began exploratory research on fuel elements for nuclear submarine power reactors. In the early 1960's, the Shenyang Institute of Metallurgy organized a special laboratory and undertook research concerning element core technologies. The tasks were transferred to the Element Laboratory at the Baotou Nuclear Fuel Element Plant [at Baotou in the Nei Monggol Autonomous Region] after it was established.

Work to develop power reactor elements was technically complex and extremely difficult. The Element Laboratory cooperated with the Shenyang Institute of Metallurgy to attack and overcome the various technical problems encountered during the development process to develop test elements that satisfied technical standards at the beginning of 1966, and they were placed in the reactor for testing in May 1966. The successful

development of the test elements pushed work to develop nuclear submarine power reactor elements past a difficult technological point and led to the discovery of more rational technical conditions and control parameters. The test elements, however, were produced at a small scale under laboratory conditions, so there was a definite disparity from large scale production.

In August 1967, the Central Military Commission issued a special official letter concerning accelerating the pace of nuclear submarine development. The Second Ministry of Machine Building Industry decided to establish a shop to produce the elements for a nuclear submarine power reactor to take up development and the cadres, engineers, technicians and workers involved in production tasks for the elements fought for time, strove for speed, thought of methods and utilized a plant building originally prepared for another shop to establish an element production shop for nuclear submarine power reactors. They quickly made preparations for production and produced the fuel elements used in the land-based model reactor and nuclear submarine reactors in 1970.

To obtain products meeting specifications as quickly as possible, the plant at first adopted a simple method to produce heavy ammonium uranate. Although the timely application of materials was guaranteed, the technology was rather backward. In 1970, the S&T personnel engaged in this item of production decided to adopt a continuous precipitation and spray drying technology. After designing and manufacturing the equipment and careful testing, a successful test of the technology was made in early 1973 and examination at a production scale was carried out. This eliminated the outdated technology of batch precipitation, reduced the number of ovens by eight, greatly reduced the labor intensity for workers and improved productivity.

Throughout the process of developing fuel elements for nuclear submarines, various technical problems that appeared during production were solved quickly because of adherence to the two types of "three integrations," involving integration of workers, technicians and cadres, and integration of scientific research, design and production. During trial production, attention was paid not only to the output products but also to continual improvement and perfection of technical conditions and technological standards to improve technical levels and product quality.

After 9 years of operational testing in the land-based model reactor, the quality of the fuel elements for nuclear submarines proved excellent and fully met the original design requirements.

Chapter 10. The Light Water Cooled Graphite Moderated Production Reactor [pp 204-215]

[Text] Like U-235, plutonium-239 is an important charge for nuclear weapons. It uses U-238 as a raw material and is formed by irradiation in a reactor. It does not exist in nature. A light water cooled graphite moderated production reactor uses graphite for a moderator and water for cooling, and is a reactor that is used especially for the production of charges for nuclear weapons. A production reactor generally uses natural uranium metal elements as fuel. In the reactor, a fission reaction occurs when the U-235 in the natural uranium absorbs neutrons, releasing neutrons and energy. Some of the neutrons are used to sustain a fission chain reaction, while some are absorbed by the U-238 in the natural uranium, with the U-238 that has absorbed the neutrons being converted into plutonium-239.

Preparations for construction of China's first light water cooled graphite moderated production reactor began in the late 1950's and it was completed in 1966. Its completion and operationalization indicated that China's nuclear industry system had entered a new stage of development.

Section 1. Starting Points and Setbacks

The construction of China's first production reactor was assisted by the Soviet Union and began in the late 1950's. On 30 January 1958 a site was chosen in Jiquan Prefecture, Gansu Province for the production reactor. In April 1958, our Soviet counterparts began the preliminary design of the production reactor. According to the stipulations of the contract, a work group with Zhou Tie [0719 6993] as group leader and Ye Decan [0673 1795 3503] as deputy group leader was to go to the USSR and participate in the designing. The members involved in reactor construction were Chief Design Engineers Ouyang Yu [2962 7122 0056] and Bi Fanmin [5643 0416 3046]. They worked in the Soviet Union for 4 months and eventually completed their preliminary design tasks. The construction design of the production reactor was the responsibility of the Design Academy in the Second Ministry of Machine Building Industry at that time (afterwards, it became the Beijing Institute of Nuclear Engineering Research and Design), and the Soviet Union dispatched experts to China for guidance. The construction design formally got underway on 21 April 1959. Because of close cooperation between the Chinese and Soviet technicians, the design work proceeded quickly. By the last half of 1960, some 60 to 70 percent of the construction blueprints were completed. The No 102 Company and No 103 Company, which were in charge of the civil construction and installation tasks, had already gone to the site to begin preparations for construction. Ground was broken for the earthworks engineering in March 1960 and the project advanced rapidly. The foundation of the reactor building basically had been completed and the concrete baseplate poured by August 1960.

Just as the design work for the production reactor and project construction were proceeding rapidly, the Soviet government broke the treaty agreements. On 22 August 1960, all of the Soviet experts at the Design Academy left and at the same time supplies of all technical data and

equipment and materials were cut off. This placed the entire reactor project in a difficult situation: only a small part of the equipment to be supplied by the Soviet Union had been received, and most of that was unwieldy exterior equipment. None of the key components, equipment, technical piping, main pumps, heat exchangers or other things had been received. Because of the lack of the necessary materials, equipment and technical parameters, there was no way for construction design to proceed, so the project was forced to a temporary halt.

Section 2. Exploration and Advance

After being cut off by the Soviet government, the builders of the reactor project responded to the call of the central authorities and began checking on the designs, equipment and materials with substantial assistance from throughout China to rely on our own efforts with a will to make the country strong, and made a major effort to develop trial manufacture and research and experiment work for the materials and equipment to move forward rapidly with construction of the production reactor.

1. Intensive exploration, developing experimentation

The key components in a light water cooled graphite moderated production reactor are the fuel elements, the technical pipes and the graphite in the reactor core. The Soviet Union only provided preliminary design charts for the fuel elements and the technical pipes, and all of the graphite had not been received. To develop these central components, under guidance by the principle of "testing everything, feeling the rocks to cross the stream" proposed by the Second Ministry of Machine Building Industry, the scientific research and technical personnel in the Institute of Atomic Energy, the Design Academy and the Jiuquan Integrated Atomic Energy Enterprise Reactor Plant worked in conjunction with engineers and technicians in the fuel element plant and in the No 101 Plant and No 201 Plant in the Ministry of Metallurgical Industry to undertake large amounts of experimental research and trial manufacture work.

The Baotou Nuclear Fuel Element Plant had primary responsibility for developing the fuel elements. They obtained products that met specifications in October 1965 and guaranteed the loading requirements of the production reactor.

The aluminum alloy technical pipes are the pipes in which the fuel elements are installed in the reactor core. Extremely strict demands are placed on the physical, thermal, hydraulic, material and mechanical performance of the technical pipes during reactor operation. The No 101 Plant in the Ministry of Metallurgical Industry began attacks on key problems in trial manufacture in 1960 and after several years of effort went into formal production in 1966. This accomplishment received an achievement award at the National Science and Technology Conference in 1978.

Taking up most of the space in the core of the reactor are the graphite bricks that serve as moderators. The graphite used in the reactor must have excellent mechanical and radiation qualities, and it must be of extremely high purity, so the techniques used to manufacture it are much more difficult than common industrial graphite. To assure the reactor core installation needs, the No 201 Plant in Jilin coordinated with the Institute of Atomic Energy and the Academy of Design, and over several years of technical research, they carried out a large amount of mechanical performance and nuclear performance tests and in the end were able to produce graphite bricks and pipe sets that met specifications on schedule.

The physical design of the reactor core directly concerns the safety and reliability of the reactor. After shifting to the use of Chinese-made fuel elements, technical pipes, graphite bricks and so on, the question of whether or not the physical characteristics of the reactor core had been affected was a troubling question for the design personnel. To assure quality, the Academy, under primary leadership of Ouyang Yu, began recalculating the physical characteristics of the reactor core at the end of 1960 based on new materials data. At the same time, the Academy also made calculations concerning thermal hydraulics and shielding and developed associated broad-ranging experimental research concerning control targets. In 1962, they undertook research on fuel changing programs for the production reactor and formulated the first fuel exchange program for the light water cooled graphite moderated reactor. By 1965, the Academy had completed its task of compiling comprehensive instructions concerning light water cooled graphite moderated reactor design.

In 1964, the reactor core plant established a special physical startup group headed by Engineer Zhou Ping [0719 1627] that began the various items of preparatory work for physical startup of the reactor. To examine the physical performance of the reactor core and understand problems that might be encountered during the physical startup, the Academy, the reactor plant, and the Institute of Atomic Energy carried out a joint examination of the graphite indices.

Between the end of 1960 and the fall of 1966, the S&T personnel undertook a large amount of research and experiment work which included calculation of temperature coefficients for the reactor core, calculations for protecting layers for the reactor, experiments concerning the hydraulics of the technical pipes and fuel element states, throttle chamber hydraulics experiments, pagoda-shaped valve hydraulics experiments, control rod system hydraulics experiments, reactor startup model installations, anti-vibration research for return circuit systems and so on. It was precisely this comprehensive and solid experimental research work that guaranteed the successful startup and operationalization of the reactor. It also trained a group of reactor engineering technicians.

2. Nationwide cooperation, development of equipment trial manufacture

Because the Soviet Union shut off sources of goods, the question of whether or not China could depend on its own resources to make up for the large amount of equipment and instruments required for the production reactor became the key to whether or not the production reactor could be built. For this reason, the Second Ministry of Machine Building Industry issued a clear task of "a major focus on trial manufacture of equipment and materials" at a work conference held in December 1960. The method was to depend on substantial nationwide cooperation.

To examine the details, a complete re-examination of the design was carried out in 1960 and the situation concerning the equipment that had been received was clarified. In January 196l, the Design Academy in the Second Ministry of Machine Building Industry and the Jiuquan Integrated Atomic Energy Enterprise jointly formed a seven member group to re-examine the main equipment. The detailed examinations clarified the situation, so they immediately proposed the need for trial manufacture to the related departments. In March 1962, the First Ministry of Machine Building Industry and the Second Ministry of Machine Building Industry jointly established a production reactor equipment leadership group composed of leaders and experts to take responsibility for the task of arranging for cooperation to manufacture equipment for the production reactor.

At the end of May 1962, the First Ministry of Machine Building Industry convened a meeting of office and bureau chiefs and directors of military industry offices from six units including the Shanghai Machinery, Electrical Equipment and Instruments Bureau, the Liaoning Industry Office and others to arrange manufacturing tasks for the 560 pieces of non-standard equipment used in the reactor. Some 30 designers from the Academy presented detailed reports at the meeting. Subsequently, large groups of designers visited 37 manufacturing plants in 11 provinces and municipalities that included Beijing, Shanghai, Wuhan, Liaoning, Heilongjiang, and others, carried out detailed discussions concerning the equipment, and assigned the 516 equipment manufacturing tasks.

To complete the task of designing the reactor equipment, technicians in the First Ministry of Machine Building Industry and the Second Ministry of Machine Building Industry jointly established a second integrated design office and undertook work to design the equipment. From this point, the design and manufacturing work for all of the equipment got underway fully.

From February to April 1963, plants under the Third Ministry of Machine Building Industry took over the tasks of developing the electronic instruments, automatic control devices and optical instruments.

The technicians and workers in the plants that undertook trial manufacture of the equipment were able to have a glorious feeling concerning their efforts in China's atomic energy industry and made full use of their knowledge and intellect to complete the tasks for which they were responsible to the utmost degree. An example is a key piece of equipment in the reactor—the primary return circuit pump—which was assigned for design and trial manufacture to the Shenyang Water Pump Plant. This was a large non-standard centrifugal pump weighing 11 tons. The body of the pump was forged of stainless steel and its walls were 150 mm thick. Facing a shortage of materials, technicians at the Shenyang Water Pump Plant studied hard and completed the design on 28 June 1962. During the trial manufacturing process, they carried out dozens of experiments and solved key problems regarding the primary technologies in pump sealing and completely the trial manufacture tasks in time. Other examples include the heat exchangers manufactured on a trial basis at the Shanghai Boiler Plant, the large stainless steel valves trial manufactured at the Shanghai Steam Turbine Plant, the reactor mockup manufactured on a trial basis at the Beijing No 1 Lathe Plant and so on. All of them were done using only a simple block diagram and were successfully designed and manufactured on a trial basis through the joint efforts of the technicians in the relevant plants and academies of design. Supported by this sort of major nationwide effort at cooperation and after 4 years of hard work, the equipment and instruments began arriving in groups at the work site, which guaranteed the work schedule for installation of the production reactor.

3. Major efforts to push forward with capital construction

The situation of work stoppages and lack of designs at the work site were a serious pressure on the design work, but they also became a motivating force. The design personnel made a maximum effort to resume construction as quickly as possible. After a period of preparation, nine special groups made up of 98 technicians, workers and leading cadres in earthworks, installation and design units began a re-examination of the plant design in January 1961 for revision and supplementation. By the end of April 1963, the entire design of the main plant building in the reactor project had been re-examined and the revisions were complete.

To save time, the Design Academy assigned Bi Fanmin to lead a group of 15 design personnel to the site on 15 March 1962 to prepare a detailed design within 40 days. On 13 June 1962, the Second Ministry of Machine Building Industry gave its approval to the resumption of construction on the main plant building at the reactor project. This brought to an end the 1 year, 10-month stoppage to wait for designs and the scene of a bustling construction site was restored. The reactor project involved enormously large-scale comprehensive equipment that required a great deal of equipment and complex systems. To organize construction rationally, Chief

Reactor Construction Engineer Ji Xiaohong [4694 1321 1347] from the Design Academy was given responsibility for organizing the technical personnel at the Design Academy and the No 103 Company to undertake organizational design work for the construction. This measure reinforced coordination and linkages among the various projects and thereby accelerated the pace of the project.

Based on the needs in the plan to develop the hydrogen bomb, the 10th Conference of the Central Special Commission in February 1965 approved the plans of the Second Ministry of Machine Building Industry concerning speeding up the construction of the plutonium production line. To push the pace of the project even faster, an on-site headquarters was established to carry out unified leadership over the various units involved in construction at the site. Again in 1965, the Second Ministry of Machine Building Industry established a reactor startup committee headed by Bureau Chief Bai Wenzhi of the Production Technology Bureau to assume responsibility for preparations for reactor startup. The committee assumed responsibility for examining primary documents concerning a trial startup of the reactor like the "Outline Reactor Adjustment and Test Program," the "Outline Physical Startup Experiment" and so on, and they took charge of coordinating technical cooperation among scientific research, design, trial manufacture and other areas.

In the spring of 1966, the reactor project began to install the graphite bricks in the reactor core. This was a key procedure that would affect the quality of the entire project. Before the installation began, all of the installation personnel were trained. To assure the cleanliness of the reactor core, all of the installers would have their heads shaved if it were not perfectly cleaned. Special models were made to ensure that the water cooling systems were installed properly. Because high standards and strict demands were enforced on every link in construction and installation to ensure that everything was done meticulously, the quality of the entire project was guaranteed.

By September 1966, the entire installation was in place and testing of the single pieces of equipment was underway. Under the organizational leadership of Head Plant Manager Zhou Tie, CPC Committee Secretary Wang Houshan [3769 0230 1472] and Chief Engineer Jiang Shengjie [1203 5110 7132], Sun Hua [1327 5478], Head Manager of the Reactor Plant, and Chief Engineer Chen Weijing [7115 4850 2417] assumed responsibility for organizing the various aspects of reactor startup. An integrated test group composed of Duty Chief Wang Tingquan [3769 7844 6898] and others assumed responsibility for reactor adjustment and testing and operation during the startup process. At the beginning of October 1966, washing of the entire reactor and comprehensive testing began and physical startup followed.

At 1900 hours on 20 October 1966, the first uranium element produced in China's own plant achieved a sustained nuclear fission reaction in a Chinese-made reactor. The thousands of scientists, engineers, workers and cadres had finally achieved the goal for which they had worked day and night. On 31 December 1966, reactor power reached the specified 0.5 percent level for the first time. Afterwards, it was increased gradually to operating power and began operating stably.

Section 3. Renovation and Enhancement

The period from the time the light water cooled graphite moderated production reactor went into operation up to 1985 can be divided into three stages: stage one, from 1967 to the first half of 1975, was one of element renovation, accumulating operating experience and attaining the design rated output; stage two, from the last half of 1975 to 1980, was one of major development of scientific research experiments and technical innovation, when production capacity surpassed the design rated output; stage three, from 1981 to 1985, was one in which many uses for the reactor were achieved and in which dual-purpose reactor technologies were developed.

1. Equipment renovation, accumulating operating experience

During the early period after the reactor had begun operating, breakdowns occurred frequently in certain systems that seriously affected safe operation of the reactor and caused reactor power to fall below design levels. To deal with this problem, the reactor plant combined efforts to explore operating experiences with renovation work on a series of equipment.

For a period after the reactor had begun operation, accidents that damaged the fuel elements and technical pipes caused many headaches. For this reason, the operating personnel made careful studies of the accident process, sought laws in the changes in the relevant signal parameters when accidents occurred, developed a system for monitoring damage to fuel elements and improved the accuracy of accident diagnosis, all of which greatly reduced the time spent dealing with element accidents. At the same time, they cooperated with the relevant plants and scientific research departments to study the relationship between these types of accidents and the product quality of the fuel elements and technical pipes in conjunction with improvements in product quality at the production plants and thereby greatly reduced the occurrence of accidents.

Usually, unloading, replacement of the technical pipes and manipulation of the graphite casings to deal with an accident required that the reactor be shut down, which greatly reduced the effective operating time of the reactor. To assure continued operation, the reactor plant carried out operational experiments for dealing with accidents without shutting down the reactor, and they

were successful in 1970. Afterwards, they were gradually perfected through cooperation with the Academy of Nuclear Engineering Research and Design and other units, and they were successful in replacing the technical pipes, graphite casings and [fuel] loading and unloading without shutting down the reactor.

The load-bearing protective water casing must bear the weight of the entire reactor core and the other metallic structures, and it also plays a role in radiation protection and shielding. In October 1972, it was discovered that the lower part of the load-bearing protective water container which was buried in a layer of sand was leaking water. The leakage increased in 1973 and would have seriously affected normal operation of the reactor if it were not dealt with in time. To solve this problem, the reactor was shut down on 30 December 1973 and the first large-scale equipment inspection and repair was carried out. Under the leadership of Chief Engineer Jiang Shengjie, the reactor plant, the Beijing Spray Coating Plant, the No 22 Company, the Beijing Academy of Nuclear Engineering Research and Design and other units participated in the equipment overhaul work. After inspection, it was discovered that there was severe corrosion on the surface of the water container caused by improper anti-corrosion coatings and filling sand. After more than half a year of sifting experiments, a glass fiber reinforced plastic was developed to replace the coating and the sand, which solved the corrosion problem. Next, renovations were carried out on more than 30 systems, including the three return circuit water container cooling systems, unloading systems and others. The completed renovation work guaranteed that the reactor would be able to operate safely and produce stably over long periods.

The operational laws of the reactor plant were explored and experience was accumulated over a period of operating practice, and various types of regulation systems and fixed standards were perfected. In addition, they also solved various equipment, component quality and technical problems that were revealed during operation and gradually lengthened the time of effective operation of the reactor. In September 1974, the Second Ministry of Machine Building Industry convened the first production reactor experience exchange conference and made a comprehensive summarization of experiences in reactor operation, and it proposed measures for improving safe operating levels and production capacity. During the first half of 1975, the reactor attained the specified design production capacity for the first time.

2. Developing scientific research, exploiting production potential

Beginning in the last half of 1975, the reactor began sustained operation in excess of design rated output. At the same time, with a prerequisite of assuring safe operation, the reactor plant carried a great deal of scientific research, innovation, exploitation and transformation work.

The first problem encountered while trying to further increase production capacity was the low reactivity of the reactor core reserve and insufficient heat conversion capacity in the heat exchangers. In addition, the original experimental data concerning the fuel elements and technical pipes was inadequate, and there were rather substantial errors in boiling reserve data, which was another issue that had to be dealt with. Based on the research topics decided upon at the first production reactor experience exchange conference, the reactor plant, the Academy of Nuclear Engineering [Research and] Design, the Institute of Atomic Energy and other units undertook scientific research experiments and technical transformation work. The central project involved further examination of the fuel elements and a "full plant power shutoff experiment" at the reactor plant.

During the process of reactor operation, boiling of the cooling water could not be prevented under any conditions. If a full plant power shutoff accident occurred, the flow rate of the cooling water within the technical pipes would drop rapidly and it would be difficult to dissipate the excess heat generated by the fuel elements, which would cause the water temperature in the technical pipes to rise quickly and make it very easy for it to boil. To derive data concerning the boiling reserve of the reactor, a simulated full plant power shutoff experiment was carried out in 1967. The boiling reserve attained from the results of the data from this experiment was very small, so there was no way that reactor power could be increased. Experience gained through several years of operation indicated that the data from this test were not correct. To obtain more accurate data, a second true full plant power shutoff experiment was carried out on 29 August 1975. This was a large-scale comprehensive test with strict requirements. Careful test programs were formulated before the experiment and training and operating personnel undertook intensive drills. Besides those from the plant, more than 150 people from units like the Beijing Academy of Nuclear Engineering Research and Design, the Southwest Academy of Reactor Engineering Research and Design and others took part. They included participants in the test from the Southwest Academy of Reactor Engineering Research and Design who carried their instruments with them to participate in the experiment. Through the joint efforts of all the personnel participating in the test, the experiment obtained complete and reliable data concerning the boiling reserve that provided accurate safety margins for the reactor and at the same time confirmed that safe operation could be maintained in the reactor after power was increased. The results also showed that it was possible to reduce the number of operating stations for the water pumps. On this basis, the reactor plant began in early 1976 to change a single return circuit three-station main pump to two station operation. This reform could conserve 10.83 million kWh for the state at a value of 1.84 million yuan.

In 1976, Engineer Dong Yin [5516 5419] of the Production Bureau of the Second Ministry of Machine Building

Industry analyzed the fuel elements, reactor heat engineering, reactor physics and other aspects on the basis of the results of experimental research at the production reactor during the previous period as well as the original Soviet design data to study the possibility of increasing the output of the production reactor and offered some opinions. After approval by the Second Ministry of Machine Building Industry, this became the goal of struggle for increased output at the production reactor during the Fifth 5-Year Plan. To achieve the goal, the reactor plant also undertook research on a whole range of experiments. The main ones were:

(1) Reactor-following tests of the element and technical pipes. From April 1975 to February 1976, high power high thermal load tests were made at the research heavy water reactor. To gain more complete data on the properties of the fuel elements, a method involving the removal of the control rods to create peak power was employed at the production reactor in November 1976, September 1977 and March 1980 during three large-scale fuel element and technical pipe reactor-following test experiments. The results of the tests led to the relaxation of operational control indices for the power of a single pipe.

(2) Tests of the thermal performance of the one and three return circuits in the reactor. The heat transfer area of the primary heat exchangers in the originally designed production reactor was too small by 27 percent. To deal with this "congenital deficiency," the reactor plant worked in closed coordination with the Beijing Academy of Nuclear Engineering Research and Design to carry out transformations of the primary heat exchanger cores. The first primary heat exchanger to be transformed went into operation at the end of 1976. The results of measurements showed an 18.6 percent increase in the heat transfer area and practice confirmed that by merely assuring the quality of the cooling water and cleaning it at preset times, the use of an original number of the transformed heat exchangers under maximum environmental temperature conditions made it possible to transfer 110 to 115 percent of the heat at rated power. In the summer of 1978, with assistance from the Beijing Academy of Nuclear Engineering Research and Design and the Southwest Academy of Reactor Engineering Research and Design, comprehensive tests were made of the three return circuit, including the characteristics of the cooling water cycling pumps, hydraulic resistance characteristics, heat transfer and efficiency of the cooling towers used in the improved primary heat exchangers and other experiments. The results of the tests showed that under specified technical conditions, the cooling capacity of the three return circuit would permit an increase in the operating power of the reactor.

(3) Research on reinforcing reserve reactivity. After exhaustive technical discussions, under a prerequisite of guaranteeing product quality, a program for deeper fuel consumption and improved demarcation of fuel exchange regions was adopted to eliminate the cooling water for the control rods in the exterior region as well as to provide the automatic control rods with increased water compression rods and other measures to increase the reserve reactivity of the reactor. Another advantage of deeper specific fuel consumption is that it greatly conserves on nuclear fuel and even reduces the amount of post-processing.

(4) Longer effective operating time. By reducing the number of reactor stoppages due to accidents and making rational arrangements of the number and length of planned shutdowns, extending the useful life of the reactor core components and other measures, the effective operating time of the reactor was increased. The maximum yearly operating time reached 324 days, 36 days more than the original design standard.

In addition, the reactor plant also adopted several measures in the areas safe production and electricity conservation. For example, in early 1979 they organized a technical transformation of the technical pipe cluster flow rate system inputs for reactor shutdown protection and assured that whenever the flow rate in a single technical pipe fell before a total value specified for protection, an automatic protective shutdown would occur quickly, which had the effect of avoiding serious sintering of the fuel elements. It also eliminated excess lifting by the main pumps, made the primary pump impellers smaller and reduced electricity consumption.

By adopting these technical transformation measures, reactor output rose gradually and reached the increased output goal originally set for the Fifth 5-Year Plan in 1979, a year ahead of schedule. Moreover, production costs gradually fell, and the unit product cost in 1981 was only about 60 percent of that in 1975.

3. Work for multipurpose uses of a single reactor

In March 1981, the Second Ministry of Machine Building Industry convened its fourth reactor operation experience exchange conference in Beijing. The conference decided that the achievement of multipurpose uses of a single reactor should be the primary goal of struggle at the production reactor during the Sixth 5-Year Plan, and they decided to undertake technical development work to turn the production reactor into a dual-purpose reactor for producing plutonium and generating electricity.

Using a production reactor to generate electricity requires a higher return circuit thermal work coefficient. This in turn requires that research be done on whether or not the original equipment could satisfy the demands of high parameter operation, whether or not the fuel elements and technical pipes would require replacement and other questions. In 1981, the Beijing Academy of Nuclear Engineering Research and Design began doing feasibility research and proposed after comprehensive debate that a new material be used for the casings of the fuel elements. Afterwards, the Baotou Elements Plant manufactured these improved fuel elements on a trial

basis. At the same time, the Aluminum Alloy Plant of the Ministry of Metallurgical Industry developed new technical pipes for the dual-purpose reactor. Next, the reactor plant made reactor-following tests of the improved fuel elements and new technical pipes. The test results showed that the improved fuel elements and new technical pipes could satisfy the requirements for power generation.

The life of the production reactor also is an important research topic. While the Beijing Academy of Nuclear Engineering Research and Design was involved in its feasibility research, the reactor had already been operating for 15 years. As the number of operating years grew, problems appeared because of aging in the equipment and components of the reactor system. The lifespan of the reactor naturally is related to the question of whether or not power generation is economical. Beginning in 1976, the reactor plant carried out a comprehensive examination of the equipment situation at the reactor and undertook research on monitoring methods and monitoring of equipment conditions. After the first reactor lifespan conference in May 1980, research in this area was reinforced. The focus of the research is to carry out close [lit.: "slavish?"] monitoring of the hard-to-replace components in the reactor, especially monitoring of the larger components of the reactor core, the graphite bricks and the exterior of the reactor itself. The conclusion drawn after analysis of the results of inspection and monitoring were that the useful life of the light water cooled graphite moderated production reactor could reach 30 years.

In 1982, the Academy of Nuclear Engineering Research and Design set up feasibility research on the utilization of surplus heat from the production reactor to generate electricity. Also in 1982, the Ministry of Nuclear Industry convened a feasibility discussion conference and confirmed the technical feasibility of using surplus heat from the production reactor to generate electricity as well as the definite economic benefits. In 1983, the Beijing Academy of Nuclear Engineering Research and Design began preliminary designs and construction designs for the project to use surplus heat to generate electricity.

Chapter 11. Reprocessing of Spent Fuel: Section 2. Construction and Operation of the Intermediate Testing Plant [pp 227-232]

[Text] 1. An important link

Technologies in the re-processing industry in China have gone through the stages of laboratory test tube experiments, work station experiments, testing and verification in intermediate testing plants and industrialized plant production. Of these, testing and verification in intermediate testing plants is the key link.

Although China changed its technical program for the testing plant at the end of 1964, the overall aspects of the plant construction were: (1) To test, verify and improve preliminary choices concerning technical processes, and to test the performance of equipment, materials and instruments in use under real conditions; (2) To obtain a definite amount of plutonium dioxide products as quickly as possible; (3) To train all categories of production, operation and management personnel; (4) To use it for testing and verification of other post-processing procedures.

The intermediate testing plant is composed of eight projects. Its design production capacity is processing 400 kg of uranium daily and it operates for 250 days a year. It employs a Purex extraction technique that involves dissolving the element casings, joint plutonium-uranium decontamination—separation cycling (the first extraction cycle), asecond plutonium extraction cycle, plutonium tail-end anion exchange, oxalate precipitation and roasting and other procedures. Except for a work chamber used jointly for precipitation and roasting, there are two parallel A and B production lines of identical production capacity to permit continued production on one line when the other is shut down or overhauled. The highly radioactive dissolution and first extraction cycle portions are located in an equipment room behind a thick concrete shield and are operated entirely by instruments through remote manipulation. The plutonium line purification part is located in a large stearage-type hot room where operations are carried out entirely behind a leaded glass observation window with periscope monitors and using simulated mechanical hands and instruments.

This program has two major characteristics: (1) A prominent technical focus, which mainly involves testing and verification of the front-end process as well as the first extraction cycle and plutonium line part, while the liquid uranium concentrate that is separated out is stored temporarily for casual recovery later by the main plant. This provides key data and plutonium products and also saves on investments. (2) It made full use of the surplus space in former public auxiliary facilities and did not require construction of other systems, so the project went faster and saved on overall capital construction expenses.

2. A determined and concerted effort to rush construction

In November 1964, the Academy of [Nuclear Engineering Research and] Design under the leadership of chief design engineers Xie Zhongran [6200 0112 3544] and Ke Youzhi [2688 0645 0037] quickly prepared a preliminary design employing an extraction method, and it received quick approval from the Second Ministry of Machine Building Industry. On 17 February 1965, the leadership group for attacks on key problems in the nuclear fuel re-processing project decided to build the plant within the Jiuquan Integrated Atomic Energy

Enterprise. In March 1965, the Second Ministry of Machine Building Industry invited specialists from within and outside the ministry to examine and approve this preliminary design.

To complete the plant at the earliest possible date, the CPC Central Committee, State Council and leaders at all levels in the Second Ministry of Machine Building Industry gave it their close attention. On 15 February 1965, the central special committee approved the requested report from the Second Ministry of Machine Building Industry concerning accelerated construction of the re-processing project and notified the relevant departments to adopt additional measures to supply the related equipment, instruments and materials ahead of schedule to assure the pace of progress in the project. As a result, a "green light" was given everywhere in China for construction of the project, which pushed construction of the project forward substantially.

A project headquarters headed by Zhou Tie clearly pointed out that the tasks should be focused on assuring quality, accelerating the pace, striving for completion ahead of schedule and being successful on the first try. Afterwards, a sub-headquarters headed by Shi Zhusan [4258 4376 0005] was established and it began working feverishly in preparation for construction. The group also arranged the design, civil engineering and installation tasks of all of the units and also transferred over 300 employees from other sub-plants to participate all aspects of the preparation work. During this period, the state also transferred a large number of technicians and skilled workers from units under the Ministry of Chemical Industry system to go first and assist.

The design personnel were filled with enthusiasm as they "left their buildings and compounds" and departed Beijing in early April 1965 to go to the barren Gobi with its "birdless skies, grassless earth and windblown stones" to begin on-site designing. They ate and lived at the site, overcoming various problems, and within only 3 months had completed all of the designs for the construction diagrams. In August 1965, the Second Ministry of Machine Building Industry organized a construction design inspection in Beijing and issued some revised opinions. After feverish work, all of the revisions were completed by the end of 1965 and they quickly shifted to the construction outfitting stage. To predict problems that might be revealed during construction and make the most rational arrangements, some physical models were made. During the period of construction outfitting, they drilled tunnels and bridged gullies in the daytime to push toward the work site, earnestly surveying the situation for pre-drilled holes and tunnels and objects to be buried in advance. When a problem was encountered, it was quickly recorded. At night they returned to their offices and made immediate revisions. Afterwards, they also participated in adjustments and testing. Quite a few people were at the work site for a long time and spent their youth there. Deputy Chief Engineer Wang Hua [3076 5478] worked so hard on the project that his hair turned white.

To push the pace of construction, the project headquarters pointed out that there must be a prominent "push" and a grasp of "stability." Projects to prepare the conditions must go forward first to prevent delays. Forces should be concentrated for a war of elimination by working on a single project, completing it and leaving no tails. At the same time, they gave special emphasis to resolute adherence to the ideology of "quality first" and "safety first." The construction units did not wait for all of the final plans to be completed. As soon as the first set of plans was prepared, they began building ahead of schedule and broke ground to start construction in 1965. A considerable amount of engineering was required for the main plant building and the construction was complex. Civil construction and installation units worked together closely for rational organization of all procedures. Only 120 days were required until the first load of concrete grouting was placed on the roof of the main building. The employees did not distinguish between day and night, endured the scorching summer, fought the windblown sand and fostered a spirit of hard work and solid work. The Fifth Office of the No 103 Installation Company used comprehensive mathematical methods to arrange construction and carried out their activities by using every bit of time and space. At the end of 1966, capital construction at the plant building was completed.

3. Tortuous progress during interference

While the employees were imbued with revolutionary fervor and worked hard to push forward with construction, the chaos caused by the "Great Cultural Revolution" rolled onto the work site, just as construction of the project was nearing its end. At this crucial instant, the State Council and Central Military Commission sent several urgent telegrams pointing out that "safe production at this plant concerns the major cause of national defense construction in China, and all employees have the responsibility to assure stable production and absolute safety at the plant." They also sent two inspection groups to the plant to encourage integration of the two factions. While meeting with mass representatives and with military and administrative personnel from units under the Second Ministry of Machine Building Industry at the end of 1967, Premier Zhou Enlai also called on all factions of the masses to unite unconditionally, be resolute in their unity and strive to complete the scientific research and production tasks.

It should be pointed out that during those chaotic days, many cadres, technicians and workers stayed at their posts. Chief Engineer Jiang Shengjie and Deputy Chief Engineer Zhao Ruyan [6392 1172 1365] continued to provide guidance at the main plant. To assure plant safety, more than 40 people from the auxiliary plant had to carry their bags to go live near the plant in order to reduce the interference. They did as much as they could to organize the remaining personnel for the construction outfitting and inspection of actual quality. Afterwards, trials were run on single pieces of equipment and joint operation and some technical training was achieved. Next, a water test, an acid test and a cold uranium test

were carried out in sequence. These rather complete equipment trials tested the operational conditions of the equipment and instruments as well as the feasibility of certain analytical methods, and revealed completely the problems that existed. In addition, the corresponding revisions were made with cooperation by design and installation personnel.

By taking this tortuous route, the equipment testing tasks were eventually finished in August 1968, and the completion of the intermediate testing plant was announced.

4. The purpose of plant construction is realized

On 4 September 1968, the first hot uranium elements were placed in the plant's A line. It operated successfully on the first try and products meeting specifications were obtained. More than 10 days later, the B line also went into operation. After roughly a year of continuous operation, records for high output, superior quality and safety were set and production tasks for 1969 were completed 130 days ahead of schedule. Because operation was so excellent, the original 100 days overhaul period was eliminated. From 24 December 1968 to 17 January 1969, it also processed 35 batches of high specific radioactivity element that had been cooled for a short time to gain experience for future operation of the larger plant. Overall, the original goals for construction of the intermediate testing plant were realized.

The overall operation showed that the technical procedures and engineering processes of the design, which were based on full and solid scientific research, basically were successful. Product quality conformed to specifications and, except for a slightly low plutonium recovery rate, all of the primary technical indices were attained. The dissolvers and mixture settling tank extraction equipment had a definite reserve strength and could be operated at varying degrees of overload. During the testing and operationalization period, a great deal of experience was gained in technologies, analysis, equipment, materials, instruments, safety protection, startup, shutdown and other areas, and improvements were made. For example, using the waste liquid from ion exchange to dissolve the elements reduced the volume of the cleansing liquid during ion exchange and improved the central cycle pipe-shaped evaporators used to concentrate the highly radioactive waste liquid. In addition, several problems were revealed during operation. Examples included inadequate ventilation in the main plant building, easy clogging of the filters used for the dissolved liquid, accidents in the gas purification systems, inappropriate choices concerning the materials used for the steam and water drainage pipes buried in the concrete, extremely small reserve and surplus capacity in certain types of equipment and so on. Improvements were made in all of these areas in the design for the main plant.

After adjustment trials and operation, a staff that included management cadres, technical cadres and operating personnel represented by Deputy Chief Engineer Fang Zhishi [2455 0037 2514] was established and expanded. Because of the dual-line installation, the technical personnel were assigned to two groups of shifts to assure that everyone could be trained and drilled at their operating positions, which trained and formed a large group of skilled technicians for future large-scale military post-processing plants in China. Even more important was that because about 18 months' time was saved in placing the intermediate testing plant into operation, it provided a timely solution to the problem of plutonium for military purposes and provided the plutonium charge for a new thermonuclear weapon test in 1968.

Afterwards, folllowing the completion and operationalization of China's large military post-processing plant, the intermediate testing plant went through a period of decline. In mid-1970, its A line was converted over to a production line for recovering the fission products strontium-90, cesium-137 and promethium-147 from highly radioactive waste liquid, and as a result could carry out comprehensive extraction of fission products and the transuranic element neptunium-237 and research on plutonium-238 and production in small amounts, which met the needs for the development of science and technology in China. Because complete decontamination was not done during the period the plant was shut down, however, the baseline radiation level was rather high, which caused problems for future re-tooling and full utilization. Moreover, the construction schedule between this plant and the main plant was too short, so some of the experiences gained in the post-processing plant were not extended and applied in the design of the main plant.

Section 3. Construction and Development of the Military Post-Processing Plant [pp 232-239]

[Text] l. The construction process

Given the international and domestic political situation of the early 1960's, the state treated the second-stage project at the post-processing plant, construction of the main plant, as an extremely urgent need for strengthening our national defense capabilities. For this reason, design of the main plant and design of the intermediate testing plant developed in a parallel fashion.

In May 1964, the Second Ministry of Machine Building Industry decided that after adopting the extraction method for the main plant, it would begin designing programs for projects of varying scales. In July 1965, the Second Ministry of Machine Building Industry approved the construction of the main plant within the Jiuquan Integrated AtomicEnergy Enterprise. In September 1965, Chief Nuclear Chemistry Engineer in the Second Ministry of Machine Building Industry and Deputy Director of the Academy of Design Cao Benxi [2580 2609 3588], Design Leader Chief Engineer Ke Youzhi,

Professor Wang Jiading [3076 1367 7844] of Qinghua University and others arrived at the site to discuss design principles and decide major questions. In October 1965, they completed a list of project design tasks. In November 1965, the Ministerial Office Conference of the Second Ministry of Machine Building Industry approved in principle the program proposed by the Academy of Design and pointed out that "we certainly must take our own path of 'precision in products, simplicity in conditions' and strive to improve the 'three integrations' (which were in reality an integration of four things—scientific research, design, construction and production)." This provided fundamental solutions to the main problems in design programs. In the last 10 days of December 1965, the Academy of Design completed a preliminary design for a uranium/plutonium separation plant building and then sent the first group of personnel to the construction site to prepare for examination of the preliminary design.

In January 1966, Deputy Minister Qian Sanqiang [6929 0005 1730] led an inspection of the preliminary design that was participated in by 350 people from relevant units, and the meeting offered many suggestions for revision. In March 1966, a large group of personnel assigned by the Academy of Design organized an on-site design team and began working on construction plans. At the end of July and in October 1966, the respective construction designs for the uranium/plutonium separation plant building and the uranium recovery plant building were completed.

Ground was broken for construction of the project on 26 April 1966. Because of interference from the "Great Cultural Revolution," construction took more than a year longer than planned and was basically completed in 1970. The first group of uranium elements were put in place on the evening of 18 April 1970 and products meeting specifications were obtained 6 days later. This showed that China had been successful in building its first military post-processing plant.

Because the intermediate testing plant and the main plant continued to use the solvent extraction method, post-processing technologies in China not only attained international levels of the 1960's but also brought enormous economic benefits. According to estimates, the technological changeover in the two plants provided the following results in comparison with the corresponding precipitation method plant under the original design: (1) Stainless steel utilization was reduced by two-thirds; (2) The amount of engineering was greatly reduced, the total area and length of the structures for the main plant buildings were 27 and 20 percent less, respectively, than the original design, and the time required for construction was reduced considerably; (3) About 360 million yuan in total investments were saved; (4) Operating costs were cut by one-half. The scientific research, design and successful operationalization of these two projects received a major scientific and technical achievement award from the National Science Conference in 1978.

2. The days of rush building

During the process of rushed construction of the projects, personnel in the three areas of design, construction, and production united in struggle for common goals.

Comrades in the Academy of Design left the bustling cities for a construction site where conditions were harsh. Some women comrades left infants as young as 3 months with others to enable them to go to the site. Some people went in the early spring every year and did not return to Beijing until the late fall, when there was no way to continue with outdoor construction. The few comrades who had opportunities to return to Beijing spent less than 3 days at home with their relatives before resuming their long march. Once, the hometown of one comrade experienced a strong earthquake, and although he was extremely worried about the danger to his parents, wife and children, he remained at the work site to continue with the work. There also were comrades who were attacked for various reasons during the "Great Cultural Revolution," but they still worked with their utmost effort.

Because of interference from the "Great Cultural Revolution," mistakes were made concerning construction scheduling, which attracted enormous attention from the CPC Central Committee and the State Council. In early 1967, Premier Zhou Enlai issued an instruction to push forward with this project. To speed up the pace of construction, the overall plant project established a project headquarters with Comrade Zhou Tie as director and carried out a battle in five successive stages. The masses of employees embodied the highly responsible spirit of mastering their own affairs and continued to fight night and day at the work site. During the peak of the construction push, many ate and lived near the plant and did not come down for several days and nights. Nearing the tail-end of the project, the headquarters proposed the slogan of a "big 100-day battle to push this project forward and present the gift [complete it] on May 1," and a sense of even more feverish work appeared at the construction site.

According to statistics, this project and the construction of the intermediate testing plant received assistance from seven ministries and commissions of the State Council, six institutions of higher education from throughout China, 27 scientific research and design units and 23 plants. The various related plants developed and processed as many as 33,380 pieces of equipment and instruments, most of them for special uses. This was another embodiment of the broad and deep spirit of major cooperative efforts.

3. Learn from Daqing, focus on readjustment, create "six good" enterprises

During the first three operating periods after the plant went into production, the lack of experience, especially because this still was a period of chaos and widespread anarchistic ideologies, caused severe interference to production and management. Added to certain shortcomings in the designs, although the plant could operate at

load and complete production tasks, it was very hard to maintain stable operation over long periods, metal recovery rates were too low and there were anomalies in the distributional laws of radioactivity when the equipment was shut down. All of these things seriously threatened the ability of this project to have safe and sustained production. In the face of these difficulties, Chief Engineer Jiang Shengjie encouraged everyone to firm up their confidence and all of the employees also had an intense desire to change this situation quickly. In early 1972, the main plant decided to make this plant an experimental unit and to once again develop activities to learn from Daqing and to use the spirit of starting with "both wheels," the revolutionary working styles of "the three honests and four stricts" [honesty in thought, word and deed, strict standards for work, organization, attitude and observance of discipline], and a strict scientific management attitude to carry out a comprehensive renovation of the plant.

First, the plant focused on several basic systems to guarantee normal production procedures, which involved five systems for job assignments, joint shifts, roving inspections, safety and quality responsibility, and regional sanitation. Afterwards, it also gradually established an equipment safeguard system, and economic accounting system, a work attendance and checking system and a position operation method. These became known as the "eight systems and one method." At the same time, grassroots units also selected "eight primary members" from among the backbone cadres who had not left production to establish a management group and permit the workers to participate in management.

The use of these measures quickly changed the situation at the plant and there was an obvious improvement in production procedures. A situation basically was achieved in which all positions were filled, all equipment had caretakers, all valves had someone handling them and people were involved in sanitation. There were no phenomena of abandoning assigned posts, idle chat or equipment disruptions, and discipline was strengthened. Next, the plant undertook "single category position" activities, conducted a survey of the equipment and major renovations, and made continual improvements in the rate of equipment completeness. Led by the Second Ministry of Machine Building Industry and the local government, the plant went from chaos to order. In 1978 and 1979, it was called a "Daqing-type enterprise" by Gansu Province and the Second Ministry of Machine Building Industry, respectively.

Since 1980, the plant has implemented total quality control (TQC) and popularized knowledge of TQC among the employees. Every workshop and shift organized TQC groups and there was a universal adoption of control management diagrams for every post. The quality of products was assured, plant output met specifications in 100 percent of the cases, the water content of the uranium products was much lower than the design indices and the plutonium dioxide products were evaluated as superior products in the ministry.

Beginning in 1982, the plant also carried out a constructive and comprehensive reorganization according to unified deployments made by the state and implemented comprehensive control. After more than a year of effort, production procedures throughout the plant were even more excellent and there was a great improvement in the working style at the plant. Archival records were set up for 3,985 pieces of equipment and instruments throughout the plant and the equipment completion rate reached 99.35 percent. To eliminate the escapage, oozing, dripping and leakage phenomena that are quite common in chemical industry plants, close inspections were made of 160,000 valves, more than 110,000 meters of pipelines and almost 140,000 of the inspectable connections throughout the plant. The leakage rate was held below 0.03 percent and no leakage basically was achieved. The surfaces, walls, equipment and pipelines throughout the plant took on an entirely new appearance, and there was no dust, collected water or clumps of oil anywhere in the plant building, which drew praise from everyone.

Since the 1980's began, the focus has been on the overall goal of improving economic results. A principle of "assuring military technology and transferring it for civilian uses" has been implemented conscientiously, and the plant has stabilized production, reinforced scientific research, developed civilian products, completed state plans in a comprehensive fashion and attained or surpassed the highest historical levels in technical and economic indices. In May 1983, after an inspection by the Ministry of Nuclear Industry and the Gansu Province Comprehensive Enterprise Reorganization Inspection and Approval Group, it conformed to specifications on the first inspection. After this, based on the enterprise standards of the "six goods" (good consideration of the interests of the state, collectives and individuals, good product quality, good economic results, good labor discipline, good civilized production and good political work), the plant has focused on construction in three areas (leading elements, employee staffs and scientific management). On the one hand, they have focused on exploitation of intellect, development of cultural and technical make-up instruction for middle aged and young people, employee technical training and renewal of technical cadre knowledge; on the other hand, they have extended modernized enterprise management methods. By creating the "six goods" activities, the quality of the enterprise and overall economic results have been raised to new levels. In October 1984, this plant was termed a first-group "six goods enterprise" by the main plant.

4. Major efforts at technical innovation and transformation to exploit potential

Another aspect of the enormous change in the appearance of the plant was that under the leadership of Chief Engineers Gu Yuming [7357 3768 2494] and Qu Guozhen [2575 0948 6966], a major effort was made at

technical innovation and transformation to exploit potential which led to continual improvements in technical levels throughout the plant. While striving to create a Daqing-type enterprise, the employees also have shown a strong interest in fostering the spirit of mastering one's own affairs, actively using their minds, thinking of methods, finding the keys to problems and creating a high tide of interest in technical innovation. After hard efforts, innovations were made in several areas in just a few years and obvious achievements were made. Only a few of the main innovations can be described here. They include the most important project, which was a shift from three to two cycles in the primary extraction process.

In the original design process, both the uranium and the plutonium went through three extraction cycles, and there were many problems. The main ones were: an excessive loss of plutonium; severe volatility of the solvent oil used as an amine diluent which made it difficult to control the concentration of the extraction agent; and difficulty in operation of the three-phase trough used for counter-extractive precipitation. After some small experiments and several trial operations, the optimum technical conditions gradually were found, and involved elimination of the amine extraction cycle and conversion to two-cycle technical conditions. The tail-end was changed to a two-phase precipitation reaction. These reforms not only led to a substantial improvement in technical performance but also provided obvious economic benefits: they saved more than 80 pieces of equipment, instruments and valves of various types, reduced the number of operating positions by two (involving 10 fixed personnel), removed two point of metal loss, converted the solvent into a single system, saved on reagent expenditures and provided greater guarantees for safe production. At the same time, the third extraction cycle was eliminated from the uranium line, which made it possible to satisfy technical requirements under conditions of a suitably longer element cooling time and a lower degree of element specific radioactivity. This change also eliminated three metal loss points, led to substantial savings on reagent costs, reduced the amount of waste liquid discharged during the process and freed up the equipment and instruments in the cycle for use in extracting neptunium-237 isotopes.

On-line analysis is a new technology for direct monitoring and analysis of technical materials flows within the production systems at the post-processing plant. Compared with conventional sample analysis, it has advantages such as requiring absolutely no chemical processing, no damage to liquid flows, continuous measurement, conservation of manpower and materials, possibility of operation from a distance and so on. It permits rapid and timely guidance of production and also has created the conditions for automated control of production. Under the care and guidance of chemical analysis specialist Chen Guozhen [7115 0948 3791], all of the personnel in the on-line analysis group at the plant's analysis laboratory overcame many difficulties, combined work with study and, with cooperation from the Academy of Design, established five methods and set up 13 control and analysis points in just a little over one year which permit analysis of 15 aspects and made preliminary achievements. The First On-Site Conference for On-Line Analysis in the Second Ministry of Machine Building Industry was held at this plant. Afterwards, they faced problems that appeared head-on and gradually solved them. Once, a certain experiment was in urgent need of americium-241 isotopes, which were not produced in China at the time. They made a survey within the plant, took several samples and found a source. Afterwards, they experimented using the things that were available and after several dozen tries finally extracted it drop by drop from a liquid that contained less than a one percent concentration. Through several years of hard work, on-line analysis has grown to 12 methods, 49 analysis points and 65 analysis items. The number of control and analysis personnel per shift has been reduced to two or three from 20 at the beginning. On-line control analysis basically has been achieved throughout the plant.

After repeated use, the quality of the organic reagent employed in the extraction process can decline while the retained radioactivity gradually increases, which thereby affects its technical performance. For this reason, the original design called for one-sixteenth of the used reagent to be discharged and replenished daily with the same amount of new reagent. Doing so consumed considerable amounts of reagents and created much associated organic waste liquid which also was difficult to process. In later experiments, daily replacement and replenishment was converted to a closed cycle, and discharges were eliminated. Only the amount lost due to entrainment, volatilization and other causes must be replaced at fixed intervals. Practice has proven that this method is feasible. In another area, with coordination by the Academy of Design and the Northwest Institute of Modern Physics in Lanzhou, the discharged organic reagent was put through a vacuum abrupt distillation method for reagent regeneration. All of the technical indices of the tributyl phosphate and kerosene obtained through fractionation recovery met requirements and the results in use were excellent.

The large amount of radioactive and acidic waste liquid created during the post-processing process formerly was dealt with using an addition-subtraction neutralization method after "continuous evaporation—formol denitration" that was common in foreign countries. This process required complex operations, efficiency was low, purification was poor and it consumed large amounts of reagent. Moreover, accidents caused by contamination of the system were common. The result was that the waste liquid did not meet discharge standards. After a broad-ranging survey, it was decided to adopt rectification extraction-concentration to recover nitric acid. Through the efforts of the employees throughout the plant, full use was made of the original plant building and overstocked materials reserves, and in only 10

months' time the nitric acid recovery project was completed. After going into operation, it could recover 300 tons of nitric acid at a 50 percent concentration each year and save 100 tons of formaldehyde at a 37 percent concentration and 200 tons of caustic soda at a 45 percent concentration, worth 150,000 yuan.

In the area of exploiting plant potential, a series of corresponding measures were adopted which led to obvious improvements in plant production capacity while operating loads were 40 to 50 percent higher than design values. This raised the utilization rates of all of the plant's equipment, shortened the annual production cycle, greatly decreased power consumption and provided extremely apparent economicbenefits. At the same time, employees throughout the plant actively created the conditions to recover sideline products. For example, they used the existing equipment to recover neptunium-237 isotopes during the technical process, and they carried out refining, separation and extraction of very useful plutonium-238 isotopes. Another example is the dissolved tail gas "low temperature activated carbon adsorption—chromatographic separation" process to cover the very useful fission gas Krypton-85. In addition, they recovered the exhausted extractant liquid from the second extraction cycle, concentrated it and used it as a dissolving reagent. They used the condensed liquid from the second vapor during evaporation and concentration of the uranium-bearing counter solvent in the first cycle to serve as its counter solvent. They recovered nitrogen oxides from the dissolved tail gas to manufacture nitric acid. They substituted condensed liquid from the second vapor produced by the evaporation of weakly radioactive waste liquid for non-ionic water, and they adopted measures for organic phase closed circuit cycles and other measures. All of these things not only greatly reduced the amount of wastes but also conserved large amounts of reagent and improved metal recovery rates. According to statistics, processing costs have fallen by about 41 percent compared with the period shortly after it went into operation.

Besides all this, the plant also coordinated with a whole range of scientific research work done by scientific research units. In April 1977, for example, the plant used a special procedure to process the low concentration uranium in the deeply burned fuel produced by the heavy water reactor at the Institute of Atomic Energy and then extracted plutonium dioxide from it with a rather high plutonium-240 content. In another example, they transformed the contaminated mixture settling trough, counter solvent trough and second extraction cycle uranium extraction trough in the first extraction cycle into a pulse extraction column which showed an obvious improvement in technical performance. This scientific research laid part of the foundation for processing fuel elements from power reactors.

Chapter 12. Production of Thermonuclear Fuels: Section 4. Tritium Production [pp 255-256]

[Text] Tritium is used not only as a thermonuclear weapons charge, but also as a radiation source and tracer atom. This means that in addition to its uses in national defense, it also has value in civilian areas.

There are several methods for producing tritium. The primary method employed in industry is to insert lithium-aluminum alloy elements containing lithium-6 into the active region of a reactor, which produces tritium from a nuclear reaction after undergoing thermonuclear radiation. The actual production process includes the steps of manufacturing the lithium-6 targets, irradiating them in the reactor, molten extraction, removal of impurities and isotope separation.

In 1963, the Institute of Atomic Energy organized experimental research on tritium production technologies and provided the necessary data for construction of a production line. In August 1965, the Academy of Nuclear Engineering Research and Design in the Second Ministry of Machine Building Industry organized an integrated work group to begin designing the production line. They presented their program design in November 1965 and went to the work site in December 1965 to make a construction design. The entire design was completed in July 1966.

Because the plant building for the project was obtained by transforming an existing building, the civil engineering project took only 3 months. Installation of the equipment and pipelines was completed in October 1966, and the production line basically was finished by early 1967. Operational testing of the equipment began in September 1967. To deal with problems that appeared during the tests, partial readjustments and revisions were made and it went into formal production in May 1968 and produced products that met specifications. Construction of a deuterium-tritium lithium-6 production line was completed in 1972.

As output from the original design for the process was too small, operations were too complex, energy consumption was high, recovery rates were low and large amounts of materials were consumed. Not long after the project went into operation Engineer Zhang Jinsheng [1728 6855 3932] and others began conducting a great deal of scientific research and technical innovation work for the purification and hydrogen isotope separation procedures. In 1972, they also carried out a major technical transformation in the vacuum molten gas removal process. By 1979, the transformation was complete. At this time, a fundamental transformation occurred in tritium manufacturing technologies and an entirely new technical line took shape that had high output, low energy consumption and easy operation. In 1985, the new technique for tritium extraction received a third-place national award for S&T achievements. Another 23 projects have received commendations and awards from various levels.

The tritium production line was built entirely through reliance on China's own efforts. After more than a decade of improvements, the production technologies have become mature and can provide charges conforming to specifications for thermonuclear weapons.

After 1980, a tritium luminescent powder production line was completed and its products are being used in China's watchmaking industry. The tritium lamps that were developed successfully have been given to users as trial manufacture products. In addition, a sideline product helium-3 isotope separation facility also has gone into production and it produces He-3 at a 99.39 percent concentration. This placed tritium products into the civilian realm.

Chapter 13. Development and Improvement of Nuclear Weapons: Section I. Hard Pioneering Work [pp 257-263]

[Excerpts] I. Establishment of the Beijing Institute of Nuclear Weapons

In July 1958 the Ninth Bureau of the Second Ministry of Machine Building Industry established a research institute in the Beijing area. Its main tasks were to receive and digest the technical information provided by the Soviet Union on the atomic bomb, and to assemble and train technical personnel. The government of the Soviet Union had stated that it would provide China with educational models and diagrammatic information for the atomic bomb in November 1958. To receive the Soviet data, all of the personnel in the institute gave their utmost effort to participate in labor to push construction of the project. In less than 3 months' time, they completed the office building, educational model and diagrammatic information repositories and other structures. The Soviet Union continued to stall, however, and never turned over the materials.

In June 1959, the Central Committee of the Soviet Communist Party sent a letter to the CPC Central Committee formally refusing to provide technical data on the atomic bomb to China. The Second Ministry of Machine Building Industry observed the principles laid down by the central authorities and decided to rely on China's own efforts to complete the task of developing the atomic bomb. For this purpose, they immediately changed their original deployments and formulated a plan for scientific research work on the basis of China's conditions at the time and clearly stipulated that work to develop nuclear weapons must be based entirely on China's own scientific research by doing our own research, our own testing, our own design and our own installation. At the time, construction of the Northwest Nuclear Weapons Research Base Area had just gotten under way, so it was decided to create the conditions for the research work in the Beijing region. Li Jue [2621 6030], Wu Jilin [0702 7139 7207], Guo Yinghui [6753 5391 2585], Zhu Guangya [2612 0342 0068] and others made comprehensive considerations and prepared concrete arrangements for the scientific research work. In early 1960, the Beijing Institute of Nuclear Weapons began doing research and exploration concerning atomic bomb science and technology.

To adapt to the need for complete reliance on our own efforts to develop an atomic bomb, the three noted scientists Wang Ganchang [3769 3227 2490] and Peng Huanwu [1756 2719 2976] of the Institute of Atomic Energy, Second Ministry of Machine Building Industry, and Guo Yonghuai [6753 3057 2037] of the Institute of Mechanics, Chinese Academy of Sciences, were transferred to the Institute of Nuclear Weapons to serve as deputy directors. The central authorities also approved the transfer of Cheng Kaijia [4453 7030 3946], Chen Nengkuan [7115 5174 1401], Long Wenguang [7893 2429 0342] and other advanced and intermediate level scientists and researchers as well as engineering and technical personnel to participate in work to develop the atomic bomb. Although each of them had their own specializations and had never done atomic bomb research, they all worked resolutely and selflessly in specialized research and technical work over many years for the cause of national defense of the motherland to counter the nuclear threat from the superpowers, and exhibited a spirit of self-sacrifice for the nation to race quickly to their posts. These scientists and engineers worked together with physicists Zhu Guangya, Deng Jiaxian [6772 4471 0341] and others in guiding the young technicians and workers in the urgent work.

The sudden scrapping of the treaties by the Soviet Union did not destroy the confidence of the vast numbers of S&T personnel on taking on the responsibility of developing an atomic bomb, but instead strengthened their will to work for national glory. In June 1960, Minister Song Renqiong called on the scientific research personnel to foster lofty ideals, sat high goals, work with a will to make the country strong, rely on their own efforts, and combine work with study. Deputy Minister Liu Jiefu made comprehensive arrangements for tasks, guiding ideology, work methods and a whole series of questions and called on all of the employees to adapt to the rapidly changing situation in their ideology, organization and activities by abandoning total reliance on idealogy and having an unshakeable determination to overcome difficulties. All of the employees were encouraged and decided to start their studies anew. They used capable people as their teachers, worked mutually to use advantages and supplement shortcomings and at the same time made full use of intelligence and skills. Although the period was one of economic difficulties in China and material life was very hard, the scientific research personnel worked day after day and even gathered at night in the offices for hard study on scientific and technical knowledge concerning the atomic bomb, and they decided to use their own sweat and intellect to find a route to success.

In 1960, the Beijing Institute of Nuclear Weapons completed its scientific research and laboratory buildings and processing shops as well as the corresponding facilities, and they established theoretical, experimental, design and production departments (with a total of 13 laboratories). At the same time, for a blast test site, they made one on a Corps of Engineers target range in the

distant suburbs of Beijing and began physics experiments and research using blasts with small charges in an effort to explore as quickly the physical laws and testing technologies for the blasts and speed up training of the S&T personnel.

To concentrate forces for breakthroughs in the certain key links in atomic bomb technologies, the Beijing Institute of Nuclear Weapons decided in October 1960 to change the 13 laboratories in the former four departments into six laboratories and one processing workshop for: theoretical physics, explosion physics, neutron physics and radiation chemistry, metallurgical physics, automatic control and guided missiles to undertake research work in six areas. At the same time, they also coordinated with the Northwest Institute of Nuclear Weapons and established two design offices for non-standard equipment and structural engineering.

As a result of the indefatigable efforts of the S&T personnel throughout the institute and strong coordination with the relevant departments across China, all of the research and experiment tasks in every area were completed by the end of 1962 and work to develop the atomic bomb moved into the two technical design and trial manufacture stages. At this time, because the organizational pattern of the six laboratories made it difficult to adapt to the requirements of development work, it was decided to make a second transformation to a theory department, an experiment department, a design department and a production department. As the development work proceeded, the central special commission again approved the transfer of Professors Zhang Xingling [1728 5281 6875] and Fang Zhengzhi [2455 2973 4249], Engineer Huang Guoguang [7806 0948 0342] and some 126 other advanced and intermediate level engineering and technical personnel as well as advanced and intermediate level technical workers to participate in work to develop the atomic bomb. The graduates allocated by each of the institutions of higher education and polytechnic schools throughout China and students returning to China from study abroad reinforced nuclear weapons research staffs. Specialists in all fields were added gradually and a full complement of administrative and managerial cadres was assembled. This timely readjustment and supplementation of the structure of scientific research and production provided the organizational guarantees needed for smooth progress in development of the atomic bomb.

At the same time, materials supply departments created the conditions and thought of methods to provide all of the materials urgently needed for the scientific research. Because development of an atomic bomb involves multidisciplinary integration, the specifications for the necessary equipment and materials tend to be more specialized. To guarantee smooth progress in the development work, materials supply personnel in the Sixth Bureau and Ninth Bureau of the Second Ministry of Machine Building Industry ignored hardship to travel throughout China. With substantial assistance from the central authorities and relevant locak departments, large amounts of equipment and materials were provided within a rather short time through purchasing, allocation, borrowing, joint use, cooperative trial manufacture and other methods. Many units which undertook responsibility for cooperation made these tasks their focus and did everything they could to guarantee them. For the small amount of precision equipment needed that would be difficult to make in China for a period, the Second Ministry of Machine Building Industry made every effort to purchase it from foreign countries to satisfy the urgent needs of scientific research and production.

2. Construction of the Northwest Nuclear Weapons Research Base Area

After establishment of the Ninth Bureau, a site selection group for the research base area was set up quickly in March 1958 to choose from sites in Sichuan, Gansu, and Qinghai provinces. The opinion after comparison was that "Gold and Silver Beach" in Haiyan County in Qinghai Province was the most suitable and had the easiest resettlement conditions. In July 1958, the central authorities approved the construction of the base in Qinghai Province. The People's Government of Qinghai Province gave the project their close attention and decided to organized a special group headed by Qinghai Provincial Vice Governor Bi Keming [5643 0344 2494] and others to make overall arrangements for resettlement, local materials supplies, highway construction, living materials supplies and other questions. At the same time, they also decided to transfer several thousand young people in support of frontier construction to participate in building the base area. In December 1958, after receiving the preliminary design data for the base area provided by the Soviet Union, the Academy of Design in the Second Ministry of Machine Building Industry and the [Beijing] Institute of Nuclear Weapons began to develop design work for this project. Personnel were transferred from three companies in the Lanzhou Construction Bureau to the Fourth Office of the No 104 Engineering Company and the No 103 Installation Company to assume responsibility for the task of construction. To provide unified leadership for the project, construction units and building units established a Joint Preparations Office to take responsibility for all of the work involved in project construction.

To carry out construction of a project on a plateau at an altitude of more than 3,000 meters during a period of three successive years of serious disasters in China was a difficult task. Every brick and every tile, every piece of iron and timber, and even the sand and rock used in the structures had to be shipped in from more than 1,000 li away. Transportation workers had no choice but to work all day long throughout the year. The 3 years of economic difficulties coincided with the most urgent period for construction of the base area. Because of transportation difficulties, there were inadequate supplies of grain and shortages of edible oils and non-staple foods. The frost period on the plateau is a long one and there is less

oxygen, all of which made building difficult. Zhao Jingpu [6392 2417 3877], CPC Committee Secretary of the Ninth Bureau, and other leading cadres worked selflessly and shared the joys and hardships of the employees. Most of the employees treated their activities as the most important thing and under the arduous conditions of sleeping in tents and eating in the open, they struggled resolutely on the windy and snowy plateau.

The State Council and CPC Central Committee were extremely concerned with the employees building this project and allocated some soybeans, meat, vegetables and other materials in extremely short supply from throughout China to supplement them. To overcome the hardships, the base area temporarily transferred 1,500 cadres and workers to organize farming, livetock and fishery teams, reclaimed the local land and planted crops, and hunted and fished to make up for inadequate living supplies.

Because these measures were adopted, stability was maintained in the employee ranks and the project moved forward without stop. By the end of 1962, they had prepared their own small hydropower plant, machinery repair shop, blast test site, part of the explosive processing project, and a small amount of living facilities. Engineers Song Guangzhou [1345 0342 3166], Bai Dongqi [4101 2639 7871], Jiang Jing [1203 7231], and Sun Weichang [1327 4850 2490] went in succession to Qinghai to develop production preparation work.

Based on the progress made in 2 years concerning many research topics at the Beijing Institute of Nuclear Weapons and the need to carry out the first nuclear test during the winter of 1964, a substantial amount of the development work was done in the Beijing region, and it had to be transferred quickly to the Qinghai base area before they could proceed. Because the Soviet Union cut off its supply of technical data, however, the base area construction project was not fully completed at the end of 1962. This was especially true of the information required for scientific research like neutron physics, radiation chemistry and other important engineering topics, and construction of them had not gotten underway because of the lack of designs. In combination with the other projects, 100,000 square meters of additional structures were to be added in 1963, so the tasks were extremely difficult ones. Based on the decision made in the second conference of the central special commission, Zheng Hantao [6774 3352 3447], Deputy Director of the special commission office invited the Ministry of Structural Engineering, the Ministry of Communications, the Ministry of Water Resources and Electric Power, the Ministry of Posts and Telecommunications, the Ministry of Railways, the Chinese People's Liberation Army Corps of Engineers, Railway Corps and other departments for joint research and determination, with each of the departments assuming responsibility for the relevant capital construction tasks. To assure progress in project construction, the Second Ministry of Machine Building Industry, Ministry of Construction Engineering, Qinghai Province and others made a joint decision to establish a capital construction headquarters with Li Jue as general director for unified leadership over project construction. The employees who fought on the capital construction battlefront ignored the cold air and frozen ground and worked at a very fast pace to complete the auxiliary projects and equipment tasks and create conditions favorable to development of the atomic bomb.

Section 2. Breakthroughs in Atomic Bomb Technology [pp 264-275]

[Text] Work to develop the atomic bomb in China formally began in early 1960 and went through three stages up to the first successful nuclear explosion of an atomic bomb on 16 October 1964. The stage of organizing forces and exploratory research lasted to the end of 1960. The stage of grasping basic theories and key technologies and of completing theoretical designs ran from 1961 to the end of 1962. The period from 1963 to October 1964 was a stage of developing large-scale blast tests and subcritical experiments, of technical design and manufacture of an atomic bomb and finally of completing a surface burst test of the bomb itself.

1. Organizing forces and exploratory research

In the spring of 1960, scientific research personnel of the Beijing Institute of Nuclear Weapons gained a preliminary understanding from the early design data provided earlier by the Soviet Union for construction of a nuclear weapons research base area as well as from several publicly issued treatises and data from foreign countries, and began exploratory research work.

The theoretical research personnel collected relevant documentation from foreign sources and conscientiously analyzed and studied the advantages and disadvantages of "gun assembly" (also called pressure-sum type) and "implosion-type" (also called compaction type) atomic bombs. They integrated with actual conditions in China and proposed the idea of "striving for the high and preparing for the law" by focusing on the more advanced "implosion-type" atomic bomb in conjunction with theoretical calculation work for the "gun assembly." They undertook development and exploratory research on aggregate explosions, metal dynamics and compression performance, fast neutron chain reactions and other specialized topics to clarify the physical, dynamic, mathematical, and other issues needed to design an atomic bomb. Since they had no computers, the research personnel utilized regular manual calculators and electric desk calculators and used the method of characteristics for large numbers of computations on blast wave and shock wave transmission. Given the press for time, heavy tasks and limited equipment, the calculation personnel set up three shifts night and day to explore the laws of the nuclear materials compaction process for the

"implosion-type," calculating on one shift, doing analysis on the second shift and resting on the third shift. After several months of round-the-clock hard work, they finally completed their calculations for this process.

The personnel participating in processing the explosives, blast experiments and testing braved severe cold and windblown sand to study high performance explosive charge injection technologies, explore detonator structures and properties, and develop research and equipment for blast components and testing technologies. Since the material dissolving furnace had not been received, the explosives processing personnel devised a method using a material dissolving drum to melt the explosives. After roasting, they worked it carefully by hand to provide test components in a timely fashion. The test personnel ignored the fatigue from their work during the day and gathered in their cramped barracks at night to work feverishly to read, organize, and analyze data, and gradually came to understand experimental methods in explosion physics.

The research work concerning neutron physics and radiation chemistry was carried out using the Institute of Atomic Energy as a base area under leadership by institute director Qian Sanqiang [6929 0005 1730] and guidance by the physicist He Zehui [0149 3419 1979] and others. Research on pulse neutron measurements, criticality experiment physics programs and experimental charges was carried out, as was research and trial manufacture of neutron sources. The Institute of Atomic Energy was extremely concerned with this work and pulled out experienced researchers and instruments and equipment in a major effort to assure that all tasks were completed.

Research and design for blast control systems was carried out from the beginning for the goal of nuclear aerial bombs. Based on the needs of the electrical performance and testing applications of detonation control systems, it was decided to make safety, reliability and accuracy the guiding ideologies of design. In 1960, the Beijing Institute of Nuclear Weapons began research for the preliminary program. The research personnel used certain modified Chinese-designed and -made components as the foundation. They also studied electrically triggered charges and full systems.

Through the work done in 1960 and with substantial assistance by all relevant departments in China, the Beijing Institute of Nuclear Weapons had formed the basis of nuclear weapon scientific research staff and created regular work routine. They explored some key theoretical and technical problems and found ways to solve them. They also gained a preliminary understanding of certain theoretical calculation methods and experimental technologies. All of this made the employees more confident of victory. In addition, they also gained a better grasp of the complexity and difficulty of manufacturing an atomic bomb and also of the importance of studying and applying Mao Zedong Thought during their scientific research work.

In 1961, on the basis of conscientiously summarizing and analyzing work done during 1960, the institute proposed the steps and methods involved in completing atomic bomb development tasks as well as problems that required attention. They also made it clearer in their guiding ideology that the institute was to focus its work on development of the atomic bomb. In addition, they stressed that the tasks should be the focus of their scientific research to provide clearer goals for development and research in every discipline and specialization. They placed further demands on the relationship between theoretical research and experimental research. Special emphasis was given to formulation of plans and development work and seeking truth from facts, going on-site and proceeding in an orderly and step-by-step fashion. The comprehensive summarization of this stage of work was of guiding significance for better adherence to the principle of reliance on one's own efforts and independently carrying out work to develop the atomic bomb, and it laid the foundation for development of future work.

2. Grasping basic theories and key technologies

Beginning in 1961, the Beijing Institute of Nuclear Weapons moved from the exploratory stage to the stage of grasping basic theories and key technologies. The demands were: carry out intensive research on key problems and special topics that had been determined and clarify their laws and internal relationships; continue to explore those problems not clearly understood and find ways to solve them and attain a grasp of each of them in turn to lay an excellent foundation for technical design of an atomic bomb.

After the first stage of exploration, the theoretical design personnel had gained a definite understanding of the theoretical design of "gun assembly" and "implosion-type" atomic bombs and took into consideration the fact that the "assembly" required more nuclear materials and was not as technically advanced as the "implosion-type," so they decided to adopt the "implosion-type" for China's first atomic bomb. To explore physical laws and conditions during the blast process, the theoretical design personnel worked under direct guidance by Peng Huanwu [1756 2719 2976], Deng Jiaxian [6772 4471 0341] and Zhou Guangzhao [0719 0342 0664] to do a large amount of analysis and computation concerning an atomic bomb explosion process and obtained much valuable data. Deputy director Peng Huanwu of the Beijing Institute of Nuclear Weapons applied powerful theoretical measures to simplify the complicated equations and completed rough calculations for the reaction process for an atomic bomb. He scientifically divided up the various stages in the reaction process and proposed some of the primary characteristic physical quantities for

each reaction process, which played an important role in grasping the basic laws and physical images of an atomic bomb reaction. To gain a deeper understanding and analyze the physical laws of the nuclear materials compaction process for the atomic bomb, the research personnel carried out intensive research on the interrelationship between blast wave and shock waves, shock wave focusing, boundary instability and other topics. The young physicist Zhou Guangzhao began with the explosive energy utilization rate to find the maximum power of the explosive and provided a theoretical clarification of the correctness of the results calculated using the method of characteristics, which provided a penetrating understanding of the compaction process and fluid dynamics phenomena. Mathematician Zhou Yulin [0719 3022 7792] and others studied effective methods and computing procedures and made calculations on the 104 computer in the Institute of Computing Technology in the Chinese Academy of Sciences. The results were identical to the results derived with the method of characteristics. The computer programs for the entire atomic bomb were compiled on this basis to provide examples for precise future calculations. Mathematicians Qin Yuanxun [4440 0337 8113], Li Deyuan [2621 1795 0337], and others used an "artificial subcriticality method" to complete overall calculations for the energy released by nuclear materials after compaction to ultrahigh criticality. Since electronic computers were an important measure used for the theoretical research, He Guilian [0149 2710 5571], deputy director of the Theory Department, and others did much work to cooperate actively to develop, install, adjust, utilize and safeguard the computers and created rather good conditions for the theoretical research. The operating speed of the 104 computer was the fastest in China at the time and the Chinese Academy of Sciences provided preferential guarantees for the computing time needed for theoretical calculations for the atomic bomb.

The key to achieving the "implosion-type" program was whether or not the wave shape required for the "implosion-type" could be attained. To deal with this question, the explosion physics test personnel did experimental research on design of detonation components and wave-shaped convergence fluid dynamics processes. At the same time, they also undertook experimental research on the laws of blast wave transmission and high-pressure state equations. In addition, they studied the corresponding high-speed photography technologies, barium nitrate luminescence interval technologies and multi-slit scanning optical technologies, and they also worked with Lin Zhuanliu [2651 0278 7511] and others to develop electrical measurement equipment and various types of testers to deal with signal gathering during the blast tests. Qian Pu [6929 2528], deputy director of the Experiment Department, and others worked with substantial cooperation by the Beijing Industrial College, the Xi'an No 3 Institute of the Fifth Ministry of Machine Building Industry and the No 804 Plant to utilize the existing technologies and equipment in these units. After thousands of experiments and continual improvements they eventually were successful in developing a high-pressure detonator that performed excellently. Development of the explosive was done under the leadership of the famous physicist and deputy director of the Beijing Institute of Nuclear Weapons Wang Ganchang [3769 3227 2490]. The new injection technique used greatly improved the quality of the explosive components. The young engineer Dong Haishan [5516 3189 1472] and others cooperated with the Lanzhou Institute of Chemistry and Physics of the Chinese Academy of Sciences and other units to synthesize new explosives. They successfully developed new explosives and played an important role in improvement and development of nuclear weapons.

Neutron physics and radiation chemistry research was carried out through effective cooperation between the Beijing Institute of Nuclear Weapons and the Institute of Atomic Energy. Major progress was made in neutron detection, theories, experimental technologies and equipment design for fast neutron criticality experiment charges. The theoretical design personnel worked actively in conjunction with nuclear physics experiment personnel to carry out a great deal of effective work regarding various types of subcriticality characteristics methods, neutron sources of different energy spectra, different structures of active region systems, criticality extrapolation curves for various locations for the emplacement of neutron sources in active regions and so on. The physics program design personnel for the criticality experiments worked in conjunction with equipment design personnel to propose rational design technology indices and to formulate a criticality experiment equipment program. A great deal of exploration also was carried out on neutron sources. After several months of day-and-night struggle, the young scientists in the Institute of Atomic Energy and Wang Fangding's [3769 2455 1353] group successfully developed the neutron source materials used for the nuclear blast test of China's first atomic bomb and completed preparation of neutron sources.

The Beijing Institute of Nuclear Weapons cooperated with the Jiuquan Integrated Atomic Energy Enterprise to organize joint attacks in Beijing on key problems concerning purification, casting and machine processing of the enriched uranium components, analysis and inspection technologies and other things. In addition, the Baotou Element Plant also did a great deal of work on development of uranium-poor components and was successful. In 1960, after determination of a preliminary plan for detonation control systems, the Beijing Institute of Nuclear Weapons undertook additional work to develop the various components and assemblies. Some of them were completed through joint cooperation with relevant plants under the Third Ministry of Machine Building Industry and the Fourth Ministry of Machine Building Industry. On this foundation, they again carried out platform testing of the entire system and analyzed the performance of the whole system. Engineers

Hui Zhongxi [1920 0112 6932], Zhu Guoliang [4376 0948 4731, and others successfully studied electrical triggering charges for use in the blast tests.

Under the leadership of the famous scholar and deputy director of the Beijing Institute of Nuclear Weapons Guo Yonghuai [6753 3057 2037] and Design Department director Long Wenguang [7893 2429 0342], the development personnel worked in conjunction with blast testing to make structural designs for the different types of test charges and, based on the special needs of theoretical design and blast testing, they integrated with future weapons needs for structural design of atomic bomb charges. To gain a deeper understanding of experimental requirements, Engineer Wu Daixian [0124 0108 034l] and others took part in rather long-term blast test activities. They studied with the design personnel to analyze the test data and to gain an understanding of the design requirements for the blast. Experimental departments and design departments worked together to complete two design programs suitable for use in the blast tests. In addition, they studied overall programs for a nuclear bomb to be delivered by aircraft and also did bomb ballistics tests and designed an overall arrangement.

From 1961 to 1962, guided by the principles of "reliance on one's own efforts, making technical breakthroughs, safety first and quality first," the S&T personnel in the various scientific fields within the Beijing Institute of Nuclear Weapons studied together and worked hard. They were able to complete research on each of the specialized topics and took steps to achieve linkage among all fields. Theoretical, experimental, design, manufacturing, materials supplies and other departments cooperated as one, and close integration of leaders, S&T personnel and workers through continual practice permitted them to overcome a variety of problems and eventually to gain an understanding of a large number of theoretical, design, experimental and processing technologies in a rather short period of time. They victoriously completed one planned theoretical design and three key tests involving an explosion physics experiment, an aerial ballistics experiment and an automatic control system platform experiment. They gained rich experience and provided the necessary technical preparations for large-scale atomic bomb simulation experiments and technical designs for atomic bomb charges. During this period, Deng Xiaoping, Peng Zhen, Chen Yi, Nie Rongzhen and other leaders in the CPC Central Committee, the State Council and the Central Military Commission expressed their concern and encouragement to the personnel who were developing the atomic bomb.

3. Technical designs and attacks on key problems with the atomic bomb

In September 1962, in accordance with the achievements in nuclear weapons research, testing and nuclear materials production at the time as well as with construction of the Northwest Nuclear Weapons Development Base Area, the nuclear blast test site and other conditions, Ministers Liu Jie [0491 2638], Li Jue [2621 6030] and Wu Jilin [0702 7139 7207] of the Second Ministry of Machine Building Industry studied and analyzed the situation regarding progress in nuclear weapons research work at the time and proposed the goal of struggling to carry out the first nuclear blast test of an atomic bomb within 2 years. They planned to use 21 months to complete preparations for the atomic bomb test charged and to carry out a nuclear blast test in the winter of 1964. They felt that hard work would enable them to carry out an atomic bomb nuclear blast test during the winter of 1964, but its success would require "rigid conditions." After a week of full discussion and research, the Beijing Institute of Nuclear Weapons proposed that a report be submitted to the Second Ministry of Machine Building Industry asking that it provide the capital construction projects, additional personnel, equipment and other conditions needed for completion. At the same time, under a prerequisite of being able to satisfy these conditions, they arranged for planned progress to assure the completion of these tasks and assigned them to the various laboratories. On 10 October 1962, the leaders of the Beijing Institute of Nuclear Weapons submitted their report to Vice Premier Nie Rongzhen, National Defense Industry Office director Luo Ruiqing [5012 3843 0615] and the leaders of the Second Ministry of Machine Building Industry. The overall plan was divided into five stages and included 15 months to complete the technical design of the atomic bomb product amd 21 months to complete preparations and carry out the test. The progress was arranged in a series of links and was extremely tight.

To reinforce technical guidance over the design and testing of the atomic bomb charge and the aircraft-carried bomb, four technical committees were set up under the Beijing Institute of Nuclear Weapons: a Product Design Technology Committee with Wu Jilin as committee chairman and Long Wenguang as deputy committee chairman and committee members Xiao Fenglin [5135 6646 7207], Su Yaoguang [5685 5069 0342], Shu Songgui [3990 2646 2710[, Zhou Yulin and Gu Caiwei [6253 2088 0251]; a Cold Test Committee with Wang Ganchang as committee chairman and Chen Nengkuan [7115 5174 1401] as deputy committee chairman, with members Deng Jiaxian, Qian Pu, Zhou Guangzhao, Li Jiayao [2621 0857 1031] and He Wenzhao [0149 2429 6856]; a Field Test Committee, with Guo Yonghuai as committee chairman and Cheng Kaijia [4453 7030 3946] as deputy committee chairman, and members Chen Xuezeng [7115 1331 1073], Zhao Shicheng [6392 0013 6134], Zhang Hongjun [1728 1347 6874], Qin Yuanxun and Yu Daguang [0205 1129 0342]; a Neutron Ignition Committee with Peng Huanwu as committee chairman and Zhu Guangya [2612 0342 0068] as deputy committee chairman, with members He Zehui, Hu Renyou [5170 0088 1342], Lai Zuwu [6351 4371 2976], Huang Zuqia [7806 4371 3174] and Chen Hongyi [7115 1347 3015].

To move forward in large-scale blast testing, a large number of experimental personnel were transferred to

the Northwest Nuclear Weapons Development Base Area in early 1963. To achieve better coordination between theoretical work and the experiments, the Theory Department dispatched a work group to the site composed of Hu Side [5170 1835 1779] and other young researchers with test personnel to participate and jointly solve the theoretical problems encountered during the test and to notify theoretical research departments of the situation as necessary. Under the concrete leadership of Wang Ganchang and Chen Nengkuan, the Experiment Department undertook a series of reduced-dimension partially-aggregated blast tests during the first half of 1963 and gained a rather comprehensive understanding of explosion laws. They also did research on explosives processing technologies, assembly and inspection of the test components and various types of measurement technologies.

In November 1963, a reduced dimension simulation of the entire blast test was carried out. This was a crucial test for comprehensive examination and approval of the theoretical design and the results of several tests. This test involved a certain amount of theoretical and technical creativity and the test results attained the predicated goals. To measure pulse neutrons, Tang Xiaowei [0781 1321 1218] and other young researchers worked under the guidance of older scientists to complete development of monitoring systems and met the requirements for this test. The success of this experiment solved key technical problems in development of the atomic bomb and laid a reliable foundation for atomic bomb design and nuclear blast tests.

Under the organizational leadership of Chen Hongyi, Yang Yong [2799 1661], Song Jiashu [2646 1367 2885], Xu Jiqian [1776 1015 0051] and others, the Beijing Institute of Nuclear Weapons and the Jiuquan Integrated Atomic Energy Enterprise repeated the experimental research and decided on technologies for casting and finishing the enriched uranium components. They also obtained technical data on refining, casting, crucibles, vacuum removal, cutting technologies and other technical data, and they established analysis and inspection methods which clarified principles for controlling contaminant content. These achievements laid the technical foundation for manufacturing enriched uranium components.

During the last 10 days of March 1964, which also was the eve of starting production of the first atomic bomb test charge, the Northwest Nuclear Weapons Development Base Area held discussions to select and determine the primary explosive technology measures for the atomic bomb charge structure program. Liu Jie, Li Jue, Diao Junshou [0431 4596 1108], Wu Jilin and other leaders as well as the relevant experts participated in the meeting. Based on the results of tests on the environmental conditions required for the structural components, the conference decided to select a rather strong program to provide even greater guarantees that the components needed for the nuclear blast test were manufactured in a timely fashion. Regarding the question of selecting the processing technologies to be used for the large-scale components, Liu Jie confirmed the two types of research methods developed to improve the quality of the explosive material, but he pointed out that since time was pressing, a decision should be made quickly to decide on the injection technique that would be used to test the first atomic bomb charge.

On 6 June 1964, a full-scale blast simulation test was carried out. With the exception of the fact that nuclear materials were not used, all of the other components used the materials and structure that would be used during the atomic bomb charge nuclear blast test. The detonation system also used systems like those that would be employed during the nuclear blast test. This was the first comprehensive preview before the atomic bomb charge nuclear blast test. Complete success was achieved in the experiments and they indicated that the atomic bomb charge nuclear blast test would be successful.

In June 1964, the trial manufacture, installation and adjustment of the fast neutron subcriticality experiment charge was completed and subcriticality measurements were made. To assure safety and prevent unfortunate accidents, "perfectly safe" safeguard measures were adopted. Besides the physics personnel, electrical personnel and mechanical personnel in each shift in the test, special safety inspection personnel were put in place and it was demanded that all of the personnel observe safety regulations and strictly implement a job responsibility system so that everyone carried out their jobs conscientiously and meticulously. To avoid damage to the nuclear materials components that would be used for the first atomic bomb test, all of the container opening and installing operations were carried out manually and according to careful procedures. At the time of the blast, Zhu Guangya and other leaders were present at the site. The results of the test showed that all of the existing breeder systems were in rather intense subcriticality, and the estimate was that even under the harshest conditions, supercriticality accidents in the nuclear material would not occur even if something unforeseen happened during the installation process or after installation. This experiment served as the basis for the formulation of subcriticality safe operations regulations.

Not only was a high degree of precision required for the components in the atomic bomb blast charge, but some of the components also were of unusual shapes and hard to process. The finishing, processing and inspection of some of the key components was very hard. To solve these problems, director Song Guangzhou [1345 0342 3166], deputy director Cai Sibo [5591 1964 3134] and others in the First Production Department organized engineering and technical personnel as well as production workers to undertake attacks on key technical problems. Liu Jie personally visited the shop to encourage the workers and technical personnel to firm up their confidence and overcome difficulties. After a rather long

period of experimental research, they eventually overcame the technical problems and produced products meeting specifications. The production and processing of the explosives was carried out under the leadership of Second Production Department director Qian Pu, deputy director Wu Yongwen [0702 3057 2429] and others. The workers and technicians made continual improvements in production technologies to attain quality requirements and safe production and provided a large amount of components meeting specifications for the atomic bomb charge nuclear blast test and explosion physics experiments. To speed up the manufacture of enriched uranium components, Zhu Linfang [4376 7792 5364] proposed and took responsibility for organizing simple workshops and after repeated testing by Zhang Tongxing [1728 0681 2502] and others, internal pore faults in the cast components and other technical problems were solved and blanks that conformed to requirements were cast at the end of April 1964. At this time, the Third Ministry of Machine Building Industry completed manufacturing tasks for the large metallic components used in the atomic bomb charge.

After 21 months of arduous efforts, the theory, testing, design and production of the atomic bomb had been completed according to plans. On 20 July 1964, under organizational leadership by Second Production Department deputy director Cai Baozhen [5591 2128 4176] and others, the engineering and technical personnel and the workers responsible for subassembly and final assembly of all of the components rushed into the assembly work. They formulated technical procedures and operating regulations on the basis of research achievements on assembly techniques during the earlier stages. Everyone was deeply aware of the seriousness of their burden and made no mistakes during the final assembly process. Every component was installed carefully and strictly inspected according to the demands made in the final assembly procedures and regulations, and everything was done meticulously and conscientiously. Worker Wang Huawu [3769 5478 2976], who was responsible for assembly of the nuclear core components, held several operational drills before the actual assembly and this assembly was successful. Installation of the atomic bomb test charge was completed on 19 August 1964. Inspections showed that the quality met to requirements and that success in the first nuclear blast test was certain.

4. The atomic bomb charge nuclear blast test

From 25 to 30 August 1964, comprehensive rehearsals prior to the nuclear blast were carried out at the Xinjiang Nuclear Weapons Test Base Area. The test base area had made comprehensive preparations for this nuclear blast test in engineering measures, communications and transportation, reserve strength guarantees and other areas. After shipping the atomic bomb test charge over a long distance, it was inspected at the test base area and the quality still met requirements fully.

This surface nuclear blast test was carried out according to schedule in the plan approved by the CPC Central Committee. Its purposes were to determine the correctness of the theoretical design and the rationality of the structural design, as well as the reliability of the operations of each of the systems in the whole charge; to measure the overall power and nuclear materials utilization rate of the blast; to observe the various physical phenomena of the nuclear blast and to measure radioactivity distribution conditions. This would answer the question of whether or not the atomic bomb would be "effective" or "ineffective." If it was "effective," then an aerial blast test of an atomic bomb could be carried out within a relatively short period of time.

The first atomic bomb charge nuclear blast test was carried out under the personal leadership of Premier Zhou Enlai. He listened to many reports from the development process to the nuclear blast test and gave many extremely important instructions. People's Liberation Army Deputy Chief of the General Staff Zhang Aiping assumed responsibility as commander in chief over this test and Deputy Minister Liu Xiyao [0491 6007 1031] of the Second Ministry of Machine Building Industry served as deputy commander in chief. National Defense Science Commission deputy secretary Zhang Zhenhuan [1728 7201 1403], Nuclear Test Base Area commander Zhang Yunyu [1728 5686 3768] as well as Ki Jue, Wu Jilin and others also personally guided all aspects of work at the site.

All parts of the preparation work at the test site were carried out quickly and in sequence. To assure that the test was successful, the personnel participating in the test implemented a strict system of regulations for every item. The recording instruments and optical, electrical and other testing equipment used in the test procedures were controlled remotely from a considerable distance. The test personnel carefully inspected all of the instruments, every connection and over 1,000 power lines and instruction lines. Zhu Zhankui [2612 0594 7608], who was responsible for lifting the atomic bomb test charge and the personnel guiding the lifting and suspending worked with great care to lift the test charge from its carrier into the product container and placed it on the iron tower safely with a cable hoist. The personnel who installed the detonator, connected the power sources and installed the probes worked meticulously and conscientiously under changing weather conditions. To assure safety and success, Minister Li Jue remained on the iron tower with the related technical personnel doingthe operations and continued to inspect it until the final procedure—installation of the detonator—was completed, and only left the iron tower just before the blast.

At 1500 hours on 16 October 1964, the atomic bomb charge exploded exactly at the predetermined time. China had attained complete success in its first atomic bomb charge nuclear blast. When experts confirmed that a nuclear blast had occurred on the basis of the flash of the fireball and the mushroom-shaped cloud, all the

personnel participating in the test totally forgot the anxiety and fatigue they had experienced for weeks. They raised their arms and shouted and were in a profound state of incomparable happiness. When the news spread throughout China that the test had been successful, everyone who had participated in the development work felt a sense of pride in having made a contribution to this glorious cause.

Section 3. Breakthroughs in Hydrogen Bomb Technologies [pp 275-284]

[Text] After China's first successful nuclear test, the Beijing Institute of Nuclear Weapons followed Zhou Enlai's instructions. They accelerated conversion of the atomic bomb to a weapon and shifted quickly to exploration of the hydrogen bomb. The skilled people, knowledge, equipment and organizational management gained during development of the first atomic bomb provided a rather firm foundation for the development of nuclear weapons. After 2 years and 2 months of research and experiments, a test of hydrogen bomb principles was carried out successfully on 28 December 1966. Half a year later, the first hydrogen bomb test was carried out on 17 June 1967 and it was a complete success. China became one of the four nations in the world which had grasped manufacturing technologies for the hydrogen bomb.

I. Exploring the principles of the hydrogen bomb

The basic principle of the hydrogen bomb is that a fusion reaction of the nuclei of the hydrogen isotopes deuterium and tritium releases enormous energy. There is a qualitative difference between this and the principle that employs fission of uranium-235 or plutonium-239 nuclei to release the energy and the conditions required are even more difficult to produce. Because a hydrogen bomb must be detonated by an atomic bomb, however, the two types also are related. Although the design theories and methods used for the atomic bomb can be used in a hydrogen bomb, they are totally unable to meet demands. This means that the characteristics of the hydrogen bomb must be dealt with directly through new additional research.

In September 1963, after the first theoretical design for the atomic bomb was completed, the Beijing Institute of Nuclear Weapons organized its forces to begin exploring theoretical questions related to the hydrogen bomb, including thermonuclear reactions and ways to detonate thermonuclear fuels, neutron transport, radiation fluid dynamics, two-dimensional fluid dynamics calculation methods, super-high temperature, high-pressure state equations and other specialized research, and they also did research on an atomic bomb fitted with thermonuclear materials (also called a reinforced atomic bomb) and explored the laws of thermonuclear reactions and fission and fusion coupling. After the first successful atomic bomb nuclear blast test, the Theoretical Department made a timely readjustment of structures and personnel and undertook comprehensive research on hydrogen bomb theory. Since the Institute of Atomic Energy had organized its forces to do exploratory research on questions related to thermonuclear weapons, the Second Ministry of Machine Building Industry decided in January 1965 to transfer this staff, including the physicist Huang Zuqia, Yu Min [0060 2404] in the Institute of Atomic Energy to work in the Beijing Institute of Nuclear Weapons.

In February 1965, under leadership by Deputy Ministers Zhu Guangya and Peng Huanwu, the Beijing Institute of Nuclear Weapons began to formulate plans for theoretical research to explore the hydrogen bomb. Theoretical Department director Deng Jiaxian and deputy director Zhou Guangzhao organized experts and researchers in the relevant fields to summarize the research done in the previous period and analyze the foreign situation in development of the hydrogen bomb. After full-ranging discussions, it was decided: first, make breakthroughs in hydrogen bomb principles; second, complete a theoretical design for a thermonuclear warhead weighing about 1 ton with the equivalent power of 1 million tons of TNT, and strive to carry out the first hydrogen bomb test in 1968. To lay a good foundation, measured data on fusion reactions had to be obtained as quickly as possible to gain an understanding of hydrogen bomb thermonuclear reactions and arrange for testing an atomic bomb containing thermonuclear materials. To provide the physics data necessary for theoretical research, they also arranged for measurement work concerning nuclear reaction section and state equations for the thermonuclear material.

Just as work to explore the principles of the hydrogen bomb was getting underway in earnest, Premier Zhou Enlai proposed magnificent goals for the four modernizations of industry, agriculture, national defense, and science and technology in his report on political work at the lst Plenum of the Third National People's Congress, and this aroused a high tide of courage and confidence among the scientific research personnel concerned with the hydrogen bomb. During the process of exploratory research, the research institute made full use of academic democracy and encouraged scientific research personnel to be bold in their thinking and propose new concepts and new design ideas. To improve professional levels and invigorate scholarly ideas, meetings were held to discuss isotope physics, two-dimensional calculation methods and other questions, and topical scholarly report conferences were organized. In the excellent academic environment, the researchers offered extremely creative ideas and after supplementation and perfection they suggested a broad range of ideas for exploring the principles of the hydrogen bomb. To solve problems in achieving a self-sustaining thermonuclear reaction in large amounts of thermonuclear materials, the scientific research personnel studied hard, pooled their wisdom and efforts and suggested a variety of ideas and programs. After analytical comparison, two routes were eventually selected and comprehensive calculations for

the hydrogen bomb were carried out to clarify the primary factors affecting the combustion of thermonuclear materials and the amount of energy released. From March to August 1965, the scientific research personnel worked selflessly at their tasks day and night and did mathematical simulations and analytical research on different combinations of materials and structural design models to determine the primary direction for exploring the principles of the hydrogen bomb.

In September 1965, Yu Min and others led the scientific research personnel to Shanghai and used the J-501 computer in the East China Institute of Computing in the Chinese Academy of Sciences for additional research and calculations concerning the principles of the hydrogen bomb. After arriving in Shanghai on 27 September 1965, they quickly took up their work and used their National Day holiday [October 1] to do a large number of calculations. Next, they did conscientious theoretical analysis of the mathematical simulation results of different models and discovered the relationship between several characteristic amounts of energy released during the combustion process in thermonuclear materials, and also discovered their relationship with the conditions that create a self-sustaining thermonuclear reaction. On this basis, they also did mathematical simulations of the theoretical models and eventually attained the expected result of self-sustained combustion after triggering thermonuclear materials and the release of enormous amounts of energy to explore the principles of the hydrogen bomb. After repeated debate by the relevant experts, a theoretical program for using an atomic bomb to trigger a hydrogen bomb was proposed at the end of 1965.

2. The first exploratory test

Theoretical research concerning the hydrogen bomb had to be closely integrated with testing. In the process of theoretical research during 1965, an atomic bomb test containing thermonuclear materials was carried out to derive measured data on thermonuclear materials fusion and examine the accuracy of theoretical calculations. After more than one-half of research, the Beijing Institute of Nuclear Weapons decided on a theoretical design program. During the development of the thermonuclear material components, manufacturing these very chemically active materials into components that met technical requirements required solutions for a whole series of technical and technological problems. To complete this task within the specified time period, engineer Song Jiashu and others undertook experimental research concerning finishing technologies, mechanical processing, moisture-proof coatings and other aspects and also studied rather difficult finishing problems as well as several different technical measures. After less than a year of feverish work, they mastered the technical processes and manufactured thermonuclear material components that met specifications. At the same time, they decided on diagnostic measures for thermonuclear reactions in the area of testing technologies. This nuclear test was carried out on 9 May 1966. An "internal activation indicator agent" was used for the first time in this test and measured a total neutron count of 14 MeV. This provided data on equivalent amounts of thermonuclear material fusion and also permitted exploration of the remaining tritium in the gas samples used. The results of the experiments showed that the nuclear reaction process was basically identical to the theoretical predictions. This provided measured data for research on the principles of the hydrogen bomb that was being done at the time and provided the researchers with a better understanding of the laws of thermonuclear fusion.

3. Tests of hydrogen bomb principles

In November 1965, Wu Jilin chaired a meeting to discuss scientific research and production plans for 1966 and 1967. The newly proposed hydrogen bomb principles and the key technical problems that had to be resolved to achieve them were presented at the meeting. It was felt after discussions that the adoption of the newly suggested theoretical programs to achieve breakthroughs in hydrogen bomb technologies were hopeful ones. As a result, it was decided at the meeting that forces in the theoretical, experimental, design, trial manufacture and other areas would be organized according to the new theoretical program to speed up the experimental research and make a decision concerning theoretical design programs for the hydrogen bomb as quickly as possible, and also that there would be no relaxation in research and experimentation on the hydrogen bomb charge that originally had been decided on. It also was decided that, with a prerequisite of having no effects on the experiment goals, existing component and already mature technologies would be used as much as possible in an effort to carry out a small equivalent test of hydrogen bomb principles within 1 year.

On the basis of the plan requirements, the Experiment Department formulated a blast simulation test program in January 1966 and carried out a series of small-scale tests to explore simulation experiment methods. On 30 March 1966, CPC Committee General Secretary Deng Xiaoping and others paid a personal visit to the Northwest Nuclear Weapons Research Base Area, which greatly encouraged the employees at the base area. In early April 1966, to speed up the experimental research, the Beijing Institute of Nuclear Weapons decided to organize experimental, theoretical and design personnel and gave Huang Shiming [7806 0013 2494] and other people responsibility over research on X-rays and technologies for measuring them. To make the simulation as realistic as possible, programs were designed for different materials of reduced proportions. Engineer Chen Changyi [7115 1603 1355] and others used over 100 blast simulation experiments and studies to solve key problems with the design of the trigger bomb and formulated a theoretical trigger bomb design program. Afterwards, they also carried out large-scale blast simulation experiments and confirmed the accuracy of the results obtained during the reduced proportion, substitute materials and partial simulation experiments.

The theoretical design workers worked in conjunction with the tests to determine a theoretical design for a trigger bomb and also centralized their forces for theoretical research on small equivalent amount hydrogen bombs. Using the computing methods of the time, they developed calculation methods, studied and compiled computing programs and did research on the relationship between component placement and energy release. Through their calculations, they clarified the role and effects of the trigger bomb on the hydrogen bomb and on the basis of this research they decided upon a theoretical design program for a small equivalent amount hydrogen bomb and began immediately to design and manufacture the test charge. In comparison with the previous atomic bomb test charges, this charge was more complex structurally and some components were of unusual shapes, which made design and processing more difficult. Based on the rate of progress outlined in planning arrangements, after completing the theoretical designs, only a short amount of time was spent on technical design, processing and manufacture. To solve this problem, an effective method employed during development of the atomic bomb was adopted which involved organizing theoretical, experimental, design and production S&T personnel during the development process to exchange conditions, issue mutual requirements, jointly discuss problems and finish some preparatory work ahead of schedule. Design and manufacture were done in parallel in a fight for time and the task of manufacturing the test charge was completed on schedule.

The test of principles was an extremely important nuclear experiment. Important aspects of the test preparation work concerned the choice of measured data for inspection and what methods should be employed to measure these data. In March 1966, personnel engaged in theoretical design and testing jointly discussed these questions. Test items were decided on the basis of the experimental goals. The Nuclear Test Base Area and the Beijing Institute of Nuclear Weapons assumed joint responsibiity for the measurement work. Under the guidance of Wang Ganchang and Experiment Department deputy director Hu Renyu, the test personnel conscientiously formulated testing programs and utilized laboratory conditions for repeated readjustment, examination and standardization of the probes, transmission systems and recording instruments. Based on the fact that both a fission reaction and a fusion reaction would occur during this test, personnel involved in radiation chemistry measurements made complete preparations and perfected arrangements for all aspects from sample collection to chemical processing, final physical measurements and other work.

The S&T personnel, cadres and workers were encouraged by Mao Zedong's slogan "the hydrogen bomb also should be speeded up." Through day-and-night struggles and selfless work, they spent less than a year to complete preparations for the test. A test team composed of experimental, development, production, charging, theoretical and other personnel went to the Nuclear Weapons Test Base Area at the end of November 1966. They worked in close cooperation with relevant units at the base area for smooth completion of the installation and adjustment of the test instruments and equipment as well as transport and assembly of the test charge and its installation on the iron tower. On 28 November 1966, a test of hydrogen bomb principles was carried out and complete success was attained. This test was of extremely great significance in the history of development of thermonuclear weapons in China.

4. Nuclear blast tests of the hydrogen bomb charge

After successful testing of the principles of the hydrogen bomb, the Beijing Institute of Nuclear Weapons immediately revised plans and ceased the "other hand" of experimental research to change the conditions that had been prepared for a hydrogen bomb test based on the new theoretical programs and design to complete the task of testing the hydrogen bomb as quickly as possible.

After completing the design program for the test of principles, the theoretical personnel studied questions related to the theoretical design and two-dimensional calculation methods. The successful test of hydrogen bomb principles pushed the work in this area forward. The theoretical design for the hydrogen bomb was completed in February 1967.

Since this test involved dropping the bomb from an aircraft, the safety question was extremely important. For this reason, besides a need to develop thermonuclear charges that conformed to quality specifications and making good preparations for on-site testing technologies, it also required the development of a reliably performing detonation control system. The Beijing Institute of Nuclear Weapons worked in close cooperation with other relevant units and completed on schedule the refitting of an aircraft, parachute development and aerial bomb design as well as testing and trajectory calculations work. Under the organizational leadership of the National Defense Science Commission, an Aircraft Safety Calculation Group composed of the Nuclear Test Base Area, the Third Ministry of Machine Building Industry, the Air Force Command and the Beijing Institute of Nuclear Weapons calculated and debated the safety of the aircraft personnel and the aircraft on the basis of the plane's speed, bomb release conditions and altitude of explosion, and proposed a safety debate report. In April 1967, a trajectory characteristics test was carried out at the Air Force Training Base Area and the expected demands were met.

In May 1967, all of the design, production, environmental testing and pre-test preparations for the first atomic bomb test were completed. In accordance with Zhou Enlai's instructions to "be serious and conscientious, attentive to details, safe and reliable, and completely without risk," measures were formulated to "guarantee direction, guarantee measurements, guarantee transportation and guarantee safety." Afterwards, when the first

hydrogen bomb was being transported to China's test site, Li Jue led the Experiment Team to the test site. The personnel participating in the test cooperated closely and jointly completed the preparations before the test.

Nie Rongzhen personally visited the site to guide this hydrogen bomb nuclear blast test. Before the test, to assure success and safety, there was a full-scale rehearsal of the aircraft, parachute and bomb using a weighted bomb to examine all of the procedures and activities stipulated for the actual test.

On 17 June 1967, China successfully tested its first hydrogen bomb blast. It took only 2 years and 8 months for China to move from testing its first atomic bomb to the successful testing of its first hydrogen bomb, much faster than any other nation in the world. This was another major achievement of the vast numbers of S&T personnel, workers and cadres engaged in nuclear weapons development work for achievement of the magnificent goal of modernizing national defense through arduous research and a bold high tide of science.

Section 4. Converting Nuclear Bombs Into Weapons [pp 284-289]

[Text] While the Beijing Institute of Nuclear Weapons was developing the first atomic bomb test charge, it also gave full consideration to the question of an aircraft delivered nuclear bomb and undertook designs for the structure of an aerial bomb, detonation control systems and overall deployments, as well as research and experiments on flight trajectories and various environmental conditions. After the successful test of the atomic bomb charge, tests of a nuclear aerial bomb were completed shortly thereafter on 14 May 1965. At the same time, a rather small volume guided missile atomic bomb warhead also was developed within a relatively short time.

l. Development of the nuclear aerial bomb

A nuclear aerial bomb is carried and dropped by an aircraft and is composed of a nuclear charge and detonation control system and the bomb casing that contains them to form a complete weapons system in conjunction with the aircraft that carries it. The question of how to study and design a nuclear aerial bomb for use in testing and warfare as well as fitting it onto an aircraft was a new weapons system project and concerned a very wide range of technical fields, so the tasks were extremely difficult ones.

In the Beijing Institute of Nuclear Weapons' plan for scientific research in 1960, arrangements were made for research and design projects for the aerodynamic exterior shape of the aerial bomb, the structure of the bomb, and detonation control systems.

The aerodynamic design of the nuclear aerial bomb has special requirements in comparison with conventional bombs. Because of the great power, the safety of the aircraft carrying it and the personnel aboard the aircraft must be assured. A high degree of precision is required for explosion parameter testing and the bomb must exhibit rather excellent ballistic stability when dropped. Beginning in April 1960, scientific researchers designed several aerodynamic exterior models and after a series of wind tunnel tests a reduced-proportion aerial release simulation test was carried out in late 1961 at the Artillery Ordnance Testing Range. Another full-scale aerial release model experiment was carried out in late 1962 at the Air Force Testing Base Area. After repeated comparisons of aerodynamic characteristics and continual design improvements, an exterior program eventually was decided upon as a prerequisite for the structural design.

The detonation control system is composed of four main parts: an electrical power source, a safety, a detonator and a trigger charge. The safety system must be capable of assuring the safety of the nuclear bomb prior to the nuclear blast. Different forms of mutually compensating detonators are used to assure reliable detonation at a preset altitude. Every effort was made to use existing technologies in China during all of this. To fight for time, many of the development tasks were completed cooperatively by plants and institutes under the jurisdiction of the Third Ministry of Machine Building Industry and Fourth Ministry of Machine Building Industry and the Beijing Institute of Nuclear Weapons.

All of the components and assemblies used in the detonation control system were developed successfully between 1961 and 1962. The Beijing Institute of Nuclear Weapons carried out a platform test in 1962 (a joint test of all the systems), measured the parameters and did analytical research. During this period of time, many repeated measurements and environmental simulation experiments also were carried out to determine their reliability. An aerial test of this system was made in 1963. At the time of the test, the Air Force Independent 4th Regiment assumed responsibility for organizing the flight and guaranteeing the aviation materials. The Nuclear Test Base Area had responsibility for organizing guidance and optical measurements, and they used radio remote monitoring measures to measure parameters and procedural activities. Under active coordination by all areas, the work proceeded rather smoothly and the anticipated results were obtained.

To meet the need for an aerial bomb following the successful test of the atomic bomb charge, the necessary improvements were made in the structure of the nuclear charge and it was carried with a specially-designed structure to satisfy physical and engineering requirements.

On the basis of the above-described developments, design departments designed the structure of the entire bomb, the separation planes, and deployments. After model assembly and static strength tests, an overall design for the nuclear aerial bomb was decided upon.

The aerial bomb casing was designed cooperatively by the Fifth Academy of the Ministry of National Defense Industry and plants under the Second Ministry of Machine Building Industry.

During the process of nuclear aerial bomb development, a series of surface environment tests of the components and the entire bomb were carried out. Examples include simulated railroad and truck transportation, aircraft transport, the mechanical and climatic conditions during the bomb dropping process and other experiments. To guarantee safety, extremely strict safety measures were adopted for environmental testing of the first nuclear components and pyroindustrial products and they were done through remote control. Comprehensive environmental testing of the nuclear bomb first of all involved simulation experiments and the actual materials testing was done only after safety was confirmed. A special monitoring system was designed to determine whether or not blind firing would occur in the detonator. The work to refit the aircraft used to carry the nuclear aerial bomb was done under technical requirements proposed jointly by the Air Force Engineering Department, the Nuclear Test Base Area and other units and were carried out in the Third Ministry of Machine Building Industry's No 172 Plant. The refitting was completed in August 1964.

To measure product state and motion parameters of an air burst, design departments carried out research on radio remote monitoring technologies. One thing in particular involved monitoring blind firing of the detonator, which involved rather difficult technologies at the time. The scientific research personnel required only 3 months to complete their tasks.

After work to prepare the Northwest Nuclear Weapons Research Base Area for the first nuclear bomb test was completed, the central authorities approved a state test. The personnel participating in the test arrived at the test site in April 1965 and made preparations for an aerial release test under unified guidance by Zhang Aiping. Before the formal aerial release, trial drops of aerial bombs without nuclear charges were made to measure the correctness of the nuclear bomb shape and dynamic parameters. At the same time, joint ground and air drills were held to inspect bomb release operations. After everything tested normal, Li Yuanyi [2621 3293 0001] of the Air Force Independent 4th Regiment, Yu Fuhai [0060 4395 3189] and organizational personnel flew the aircraft carrying the nuclear bomb and took off on schedule on 14 May 1965. The nuclear aerial bomb was launched accurately toward the target and exploded at the preset altitude. China's first nuclear test bomb blast test was a complete success and the force of the blast was almost identical to the theoretical design. This successful test was an indication that China had nuclear weapons that could be used in actual warfare.

To commend and encourage the personnel who had taken part in developing and testing nuclear weapons, CPC Central Committee and State Council leaders like Zhou Enlai, Deng Xiaoping, Chen Yi, Nie Rongzhen, Luo Ruiqing and others met with the responsible persons, scientists and technical experts from the nuclear weapons development and testing departments at the Great Hall of the People on 30 May 1965. Premier Zhou Enlai encouraged everyone to study diligently Mao Zedong Thought, pool knowledge and resources, guard against arrogance and impetuosity and continue to push forward.

2. Development of guided missile nuclear warheads

During the early attacks on key problems to develop the first atomic bomb, the Beijing Institute of Nuclear Weapons also undertook preliminary exploratory research on fitting an atomic warhead on a guided missile. In the spring of 1964, based on the spirit of arrangements for future work made on 31 January 1964 by the special central commission, the Beijing Institute of Nuclear Weapons formulated a development work plan for a nuclear warhead. On 21 March 1964, it also responded to Vice Premier Nie Rongzhen's instructions and suggested plans for progress in the primary design and testing projects, technologies and finalized designs and other things involved in cooperative tasks for a guided missile nuclear warhead. The volume and weight of a guided missile-carried nuclear warhead is much smaller than a nuclear aerial bomb and the environmental conditions required are even more demanding than with aircraft transport. The attainment of safety and reliability is related to the higher technical requirements for warheads in all areas.

Theoretical research concerning the nuclear charge got underway in August 1963. After computer analysis of some models, the theoretical research personnel decided on an optimum method for the theoretical design in April 1964, and they made analytical comparisons of several programs and suggested a theoretical design program. In early 1965, they began blast tests for the detonator components and simulated charges. They also carried out a large number of technical experiments and made structural designs for the nuclear charge.

Research on a detonation control system for nuclear warheads began in 1963. In 1964, the research personnel designed and tested key components like the detonator and the radio monitoring equipment, antennas and so on for flight test measurements, and achievements were made rather quickly. In addition, they designed and developed entire systems including different redundant safety systems and various types of detonators, and they also designed a self-destruct safety system.

After the above preliminary research and debate concerning nuclear warhead programs, the Beijing Institute of Nuclear Weapons discussed and revised the development plans in June 1965 and decided on four finalized designs and large-scale testing programs.

First, some of the components and assemblies used in the nuclear charge and detonation control system were subjected to vibration, centrifugal acceleration, shock, temperature, humidity, and other tests. Given the limitations in transport simulation experiment technologies and testing equipment at the time, special nuclear warhead highway transport experiments were carried out over distances of several hundred kilometers. After surface environmental testing, the first test in the "dual bomb" integrated flight test of detonation control systems was carried out in the spring of 1966 to examine the working performance of the detonation control systems during the missile flight process. The results of the tests showed that the detonation control systems had been designed correctly and worked normally. This signalled the end of development and testing work.

The next question was how to determine the performance of the nuclear warhead (primarily the nuclear charge) in an actual flight environment. Given the technical conditions at the time, a method seldom used in the world was adopted which involved an aerial nuclear blast test of a nuclear guided missile. The launch, route and point of detonation of the guided missile would be on the ground and in the air above it. Zhou Enlai was extremely concerned with this and again instructed that the safety and reliability of the test must be assured. To adhere to this instruction, the Beijing Institute of Nuclear Weapons carried out simulation tests to determine whether or not a nuclear explosion would occur should the nuclear warhead strike the ground without having its safety removed or if it burned, and they re-discussed the reliability of the detonation systems and self-destruct systems. The conclusion drawn after these safety simulation tests and analytical debate was that this test was safe and reliable. After approval by Zhou Enlai, it was decided to carry out an integrated "dual bomb" guided missile nuclear weapons test according to plans. The test personnel arrived at the test site in early September 1966 and worked in close conjunction with the personnel from the Seventh Ministry of Machine Building Industry and the Launch Base Area to implement this task jointly. Nie Rongzhen came to the site personally to provide guidance. To assure that "everything was perfect," another safety and self-destruct system flight test and two detonation control system flight tests were carried out before the formal test to provide a further confirmation of the reliability of the self-destruct and detonation systems. On 27 October 1966, a guided missile nuclear blast test was carried out. The test showed that the guided missile launch and flight went normally and that a nuclear explosion of the warhead was achieved at the preset target and altitude. The complete success in this test was achieved when China had just begun to develop guided missile nuclear weapons and lacked both experience and the difficult technologies in many area. It showed the high sense of duty, the strict scientific working styles and conscientious work attitudes of China's scientific research and engineering and technical personnel.

After this successful test, the first successful test of the hydrogen bomb also was carried out in a little more than one-half year. Afterwards, work on the use of thermonuclear warheads as weapons developed quickly.

During the nuclear weapons development and production tests, many persons made enormous sacrifices, sometimes even with their lives. After completion of the preparatory work for the first thermonuclear warhead nuclear test, Guo Yonghuai, the famous mechanics expert and deputy director of the Beijing Institute of Nuclear Weapons, was killed in a plane crash on 5 December 1968 while returning to Beijing. After being transferred to the Beijing Institute of Nuclear Weapons in May 1960, Guo Yonghuai made major contributions to creating and developing China's nuclear weapons industry in mechanics, environmental simulation, overall weapons design and other areas, and his heroic name will be remembered forever in the history of nuclear weapons development in China.

Section 5. R&D for Thermonuclear Weapons [pp 289-292]

][Text] With the successive completion of the nuclear aerial bomb, a guided missile nuclear weapon armed with an atomic bomb warhead and the successful test of a hydrogen bomb, and after achievements were made in the development of high-energy explosives and plutonium material components, the Beijing Institute of Nuclear Weapons had its own experience and foundation in scientific research, large-scale testing, design, manufacturing and other fields and it had rather complete materials and equipment conditions, so it formed a staff that was good at intersecting coordination in technical work and pushed forward boldly with a high tide of science and technology. After answering the question of whether or not there would be any nuclear weapons, they followed the principles for the development of nuclear weapons in China and immediately proposed that the conversion of thermonuclear warheads into weapons be speeded up. They made a major effort to strengthen preliminary research, explored new principles and developed new ideas on technology. However, the "Great Cultural Revolution" began in 1966 and had a major influence on the development and research. This was especially true of direct interference by the counter-revolutionary Lin Biao clique, which caused serious damage to the Nuclear Weapons Research Base Area. In these extremely difficult circumstances, the S&T personnel and other employees still focused on the interests of the nation. They were resolute in their work and continued to make achievements in scientific research and production.

After the counter-revolutionary Lin Biao clique was smashed, Premier Zhou Enlai personally oversaw the rehabilitation of a large number of unjust, false and mistaken cases in the spring of 1973. After a great deal of work to clean up the aftermath, scientific research and production gradually returned to normal. Most of the

people who had been harmed were able to see the overall situation and actively took up all aspects of their work, which changed the face of nuclear weapons research work. In several nuclear tests after 1973, concrete progress was made in improving weapons performance, developing nuclear warheads, and other areas. Based on the technical requirements of the nuclear bomb for use in short, medium, and long-range guided missiles and to assure that the corresponding environmental conditions of the nuclear warhead were safe, reliable, and easy to use, the Beijing Institute of Nuclear Weapons undertook comprehensive work for weapon conversion: it began weapon component technical experiments and established a quality standard and inspection method; it studied the reliability and environmental adaptability of detonation control systems and their reduced-scale design; it carried out weapon component and full-unit storage tests and explored the effects of storage environment conditions on weapon performance; it manufactured simulation environment testing equipment and studied experimental technologies; and it developed the ground testing equipment associated with the weapons and did research on flight test methods and remote monitoring technologies which could evaluate the nuclear charge without involving a nuclear blast.

The achievements in the above research and experiments accelerated progress in conversion to weapons. To assure quality, a series of simulation tests of weapons developed by the institute were carried out for the demands based on tactical technical indices. They include blast tests, materials and strength tests, environmental conditions tests as well as a final comprehensive examination during an evaluative flight test. Finally, it was reported to the state for examination and approval of the finalized design. Beginning in the late 1960's in accordance with plans issued by the state, nuclear weapons research and production units produced and turned over thermonuclear weapons of different equivalent amounts fitted into various types of vehicles. Moreover, they joined with the army in analyzing the quality characteristics of the existing equipment as well as extended service tests and research on retirement from service.

As the development work progressed, nuclear tests in China moved from the atmosphere to underground. The first underground nuclear test conference was convened in October 1967 under the chairmanship of Deputy Director Wang Ganchang of the Beijing Institute of Nuclear Weapons and Cheng Kaijia, director of the Northwest Institute of Nuclear Technology, and arrangements for the testing projects and rate of project progress were made. Wang Ganchang and others were unafraid of the difficulties and dangers and went to the scientific research, production and test sites to provide leadership. After 2 years of hard work by all of the employees, the first underground nuclear test was carried out in September 1969 and preliminary experience was gained in organizing this sort of test. Because of serious disruptions caused by the counter-revolutionary Lin Biao clique, the underground nuclear tests were stopped for a period of time. In March 1974, the National Defense Science Commission directed the convening of a conference to discuss and approve underground nuclear test plans. Through two underground nuclear tests in 1975 and 1976, a basic grasp of experimental testing techniques was gained which laid an excellent foundation for further development and improvement. The famous nuclear physicist Wan Ganchang participated in all of the organizational leadership during three underground nuclear tests. Although he was advanced in age, he still went personally to the site to inspect and guide and made a contribution to the development of underground nuclear testing techniques in China.

After the "gang of four" was smashed, based on the development orientation for nuclear weapons, preliminary research was carried out for development and research arrangements in theory, testing materials and components, detonation methods, detonation control systems and other aspects. Based on the achievements in all aspects of the research work and after careful consideration, a plan for a series of nuclear tests was formulated that provided new design principles for development of nuclear weapons. Because of the coordination and joint efforts of the Beijing Institute of Nuclear Weapons and the Nuclear Test Base Area, plans for an underground nuclear test were completed in 1984. During these tests, newly-developed diagnostic technologies were used to measure the physical amounts and power during the nuclear explosion process. The measured data confirmed the correctness of the theoretical design and also showed that the conditions for further development of nuclear weapons were present in experimental design, manufacturing and other technologies. The complete success in this series of tests pushed the development of nuclear weapons in China into a new stage.

Since 1960, when China relied on its own efforts for independent development of nuclear weapons and 1985, 32 nuclear tests were conducted. Though this figure is quite small compared to the superpowers, major achievements were made: breakthroughs in key scientific and technical question related to the atomic bomb and hydrogen bomb were made in 7 years and afterwards their conversion into weapons was completed and the military was armed with them. Major breakthroughs also were made in research on new types of nuclear weapons. At the same time, the Nuclear Weapons Test Base Area was constructed and a multidisciplinary staff was trained with good political qualities and high technical levels. This scientific research and production staff has been a valuable force in China's four modernizations drive.

Chapter 14. Nuclear Reactor Engineering and Nuclear Energy Applications: Section 3. Nuclear Powered Submarines and the Land- Based Prototype Reactor [pp 301-307]

[Text] A submarine nuclear power plant refers to a reactor installed as a source of power for a nuclear submarine. Conventional submarines burn conventional

fuels and have a sustained sailing distance (calculated at a speed of 10 knots) with one fueling of only about 10,000 nautical miles. Moreover, they can stay submerged only for as long as the electrical storage batteries provide power, so their submerged sailing distance is only 400 nautical miles. A single fueling of a nuclear submarine, however, can last more than 10 years and its sustained sailing capacity exceeds 400,000 nautical miles. Even with limited air regulation and supplies in the hull, however, the sustained sailing capacity still can reach 40,000 nautrical miles. Because no oxygen is required for the nuclear power plant, the distance of submerged sailing can be as much as 90 percent of the total sailing course, and the sailing speed is much greater than conventional submarines. For this reason, nuclear submarines have very great advantages in the areas of flexibility and concealability. In conjunction with guided missile nuclear weapons and other advanced equipment, they become an even greater main force warship in the modern navy. The development of nuclear submarines is of extremely great significance for strengthening modernized naval construction.

The nuclear submarine power plants currently in use in the world employ pressurized-water reactors and their return is similar to that in a land-based pressurized-water reactor power station. They are different only in that the steam generated by the submarine reactor is used not to generate electricity but instead provides power to turn the propellers. However, because their use as a battleship places a whole series of special demands on submarine reactors like small volume, light weight and a high degree of flexibility (such as being able to start or stop as needed), tolerance to shock, tolerance to vibration, tolerance to rocking, and especially a high degree of safety and reliability, and so on. All of these substantially increase the difficulty of developing a submarine nuclear power plant. To examine the correctness of the design and assure the safety, reliability and operational performance of the nuclear power plant, a 1:1 land-based prototype reactor usually must be built according to actual submarine conditions for various simulation experiments and for training personnel prior to the manufacture of a nuclear powered submarine.

China began designing and manufacturing nuclear power plants at the end of the 1950's. The engineering and technical personnel and the workers were guided by the CPC Central Committee principle of "reliance on one's own efforts" and began development and research. They relied on major efforts at cooperation for attacks on key questions and in the end victoriously completed China's first land-based prototype reactor for a nuclear powered submarine in July 1970.

1. Starting at zero, laying a foundation

In October 1958, the Second Ministry of Machine Building Industry began organizing for development and research on nuclear powered submarines. At the time, only the United States and the Soviet Union had completed nuclear submarines. They were fiercely secretive about development technologies and only published occasional reports on the general situation in some magazines. The S&T personnel in the Institute of Atomic Energy responsible for this task relied on this scattered information and worked under the organizational leadership of deputy minister Li Yi [2621 3015] and the persons responsible for the reactor work line Meng Gefei [1322 2047 7236] and Lian Peisheng [6647 1014 3932] for about one-half year to propose reactor model, power and motive power programs for selection. On this basis, further decisions were made on primary programs and parameters for the reactor. Next, they organized forces and began carrying out program designs. At the time, the Institute of Atomic Energy had put together a staff of about 200 research and design personnel. Most of them were young people who had only recently graduated from college, so they not only lacked experience but also had obviously insufficient basic knowledge. The program also called for starting with real conditions in scientific and technical levels and industrial foundations in China at the time, which also caused them to lose a great deal of freedom in their design work. Under guidance by a more experienced middle-aged S&T backbone staff, they relied on their collective intellect and strength and worked for nearly 2 years to propose the "Nuclear Submarine Power Plant Program Design (Draft)" in June 1960. This program design was reported in draft form at the time but there was no major repetition in later practice, which confirmed that the overall design was feasible. This laid an excellent foundation for later development work.

The program suggested a large number of topics that required study. For this reason, the relevant laboratories in the Institute of Atomic Energy undertook a series of research projects concerning reactor physics, reactor engineering, components and materials, thermodynamic hydraulics, automatic control and other aspects. Many of the research institutes in the Chinese Academy of Sciences and institutions of higher education also assumed responsibility for many research topics. A scientific research coordination network for the nuclear power plant began to form and development and research work got underway in a comprehensive manner. At the same time, as the technical requirements were proposed for the various pieces of primary equipment in the nuclear submarine reactor, the relevant industrial manufacturing departments throughout China began research and trial manufacture work for the equipment, materials, instruments and other aspects.

In 1962, because of the need to reduce capital construction fronts and the concurrent requirements in the centralization of forces for overall deployments for the "two bombs," it was decided that the nuclear submarine power plant project would be delayed. For this reason, design staffs were reduced considerably. The related scientific research work either stopped temporarily or slowed its pace. None of the key projects was stopped,

however, which preserved their strength and kept the required technologies in reserve. This was especially true in consideration of the rather long periods that often were required for trial manufacture of the materials, so industrial departments continued to produce the main equipment and primary materials for the nuclear island. These arrangements served as a leading force in the later resumption.

2. Speeding up the pace, struggling for the goals

In 1965, the central special commission decided to speed up work to develop nuclear submarines and called on the Second Ministry of Machine Building Industry to complete the land-based prototype reactor in 1970. Afterwards, under the direct concern of Nie Rongzhen, the pace of development work on the nuclear submarine was accelerated greatly.

The Academy of Nuclear Submarine Power Plant Research and Design quickly filled out its forces. Under the leadership of institute director Zhou Shengyang [0719 5110 3152], deputy directors Peng Shilu [1756 1102 4389], Zhao Renkai [6392 0088 1956] and others, a power reactor design program was proposed in July 1965 and received quick approval from the central special commission. A preliminary design was completed at the end of 1965, an expanded preliminary design was completed in 1967, and all of the construction blueprints were completed in 1969.

The feasibility of the design program had to be based on a large amount of scientific data. Scientific research work on nuclear powered submarines which had continued without let-up also speeded up its pace at the same time as the design work. For example, the reactor core is the heart of the reactor and a fission chain reaction must occur in it. This means that the rationality of the reactor core physical design is of major significance for the safety and reliability of a nuclear submarine power plant. To develop a program for an optimum reactor core arrangement capable of satisfying all performance requirements, a series of theoretical calculations and experimental examinations and confirmation were carried out throughout all stages of design. To carry out criticality experiments, the engineering and technical personnel established a special large-scale zero-power plant to examine and confirm the computational precision of the primary physical design parameters. Another example is that during actual warfare at sea, a nuclear submarine reactor must be capable of wide-ranging changes in power within an extremely short period of time. It must be able, for example, to increase from 10 percent to 100 percent within 30 seconds or even be capable of dropping from 100 percent to 2 percent in 2 seconds. These changes in power are achieved mainly by rapidly lowering or raising the control rods, which requires that control rod drive mechanisms must have a high degree of flexibility and reliability. To test the performance of the drive mechanisms, over 1,000 drive experiments were carried out under cold and hot states. In addition, a special hot-state experiment platform was set up for the purpose of inspecting whether or not rapid lowering of the control rods was possible in a state of extreme hull angles to satisfy the special demands made on nuclear submarine reactors. The frequent power changes also required that the equipment be tolerant to the resultant heat shock and thermal fatigue. For this reason, a large amount of dynamic testing was done on all the equipment and systems.

At the time, China had no big electronic computers, so much of the computing had to be done by hand. Using a desk-style calculator to complete a program often required that calculating personnel work overtime day and night and took more than a month altogether. All of the work related to the choice of relatively uniform power distribution coefficients for reactor core safety under full power conditions during the total lifetime required just such arduous work. A large amount of experimental results and solid calculated data provided a timely confirmation of the design to permit revision and supplementation to perfect it more. China's success in manufacturing its first submarine power reactor was due entirely to the hard work of these large numbers of S&T personnel.

At the same time, work was progressing quickly on other battlefronts in China. At the right moment, the Element Plant began trial manufacture and production of fuel elements meeting requirements. The materials testing reactor built especially for this project completed its tasks concerning inspection of the fuel elements and various reactor materials. All of the primary and auxiliary equipment and the instruments and devices were successfully manufactured on a trial basis and put through various technical tests. To reinforce unified on-site guidance over the base area, the Second Ministry of Machine Building Industry and the National Defense Science Commission's No 7 Academy decided in March 1968 to establish a work-site headquarters. The Ministry of Machine Building Industry assigned He Qian [0149 6197] as work-site commander and sent some technical backbone cadres to the site to work. This greatly accelerated the pace of project construction and the main part of the project basically was completed in late 1969. On 18 April 1970, the installation of the nuclear submarine land-based prototype reactor was completed victoriously. Testing got underway on 1 May 1970, increases in reactor power began at 0200 hours on 17 July 1970 and the experiment reached full power on 30 July 1970. This indicated that China's nuclear submarine land-based prototype reactor had been completed victoriously.

3. A battle at the seashore, the first submarine is tested

The shipyard responsible for building the hull of the submarine concurrent with construction of the land-based prototype reactor also pushed forward with construction of the hull for the first nuclear submarine. During the winter of 1970, not long after the land-based prototype reactor had reached full power, the hull was

completed and it slipped into the water victoriously. The stage of nuclear power plant installation had begun. The Nuclear Submarine Power Plant Research and Design Base Area assigned a skilled staff of key technical personnel to the coastal site to assume responsibility over construction, installation, adjustment, startup, increase of power and other technical work related to the nuclear submarine power plant. They stayed with the shipbuilders and the Navy's sailors fighting day and night in backbreaking labor to build China's first nuclear powered submarine. Engineer Li Yichuan [2621 1355 0278] of the Academy of Nuclear Submarine Power Plant Research and Design worked so hard while ill during construction of the land-based prototype reactor that he sacrificed himself at his on-site post because of fatigue from working so hard during the battle at the seashore.

The valuable experience gained by the engineering and technical personnel, the workers and the sailors during construction of the land-based prototype reactor meant that just 1 year was required to complete the task of building and installing the first submarine nuclear power plant, and it was finished victoriously in 1971. Shakedown cruises confirmed that all design performance requirements were attained with the first nuclear submarine and that China had become the fifth nation in the world to have a nuclear submarine.

4. Nine years of operation, completion of full life experiments

The nuclear submarine land-based prototype reactor reached full rated power in late July 1970, and it had gone through its full-life operational test with one loading of fuel by December 1979, completing its historical mission.

A large amount of experiments were carried out during its 9 months of operation and substantial results were attained.

(1) More than 530 tests were carried out in areas like physics, heat processing, control, chemical testing, shielding, dosages, vibration, noise stress measurement and so on. They included tests of all aspects of performance under maximum design value conditions as well as measurement and analysis of all the data. Through these experiments, the main functions of a nuclear power plant were clarified and complete sets of data on the unit as a whole for the full operating life of the reactor core also were derived. The operational tests showed that all of the data on the nuclear power plant had attained the original design indices. For example, the power distribution of the reactor was better than the design value, its self-stabilization and self-adjustment performance was excellent, there was no damage to the fuel elements, and it was put through tests to increase power, decrease power, load shedding and so on. The dynamic qualities of the power plant were excellent and were completely capable of satisfying ship engine requirements. All of these things were of extremely important guiding significance for development of the next generation of nuclear submarine power plants.

(2) The operational testing confirmed that all of the equipment, instruments and devices and their systems performed excellently and could assure safe reactor operation. In addition, operation also revealed several problems with the design, manufacturing technologies, materials or other aspects of some of the equipment systems. Improvements were made quickly in all of these problems, which laid a reliable foundation for work to finalize designs for nuclear power plants.

(3) The operation trained a large number of operating, management, maintenance, inspection and other personnel that prepared a definite technical force for development of pressurized-water nuclear power plants.

The reactor was shut down in December 1979. After a year of operational summarizations and technical preparations for opening the cover, the reactor cover was opened in 1981, after which comprehensive inspections and confirmations were made for the reactor core, the pressure vessels and all of the equipment. The results confirmed that after going through 9 years of operational wear, the main equipment in the nuclear power plant still was in excellent condition.

The main and auxiliary steam turbines showed no steam erosion and there was no serious corrosion, and the wear on the bearings and other rotating components was within the permissible range. Only a very small number of auxiliary equipment exhibited rather serious steam erosion and corrosion. This re-test showed that the overall design for the first nuclear submarine power plant designed and built in China was successful.

The work to open the reactor and remove the fuel was carried out under intensely radioactive conditions and could only be done using mechanical hands and other special tools. It demanded preparations not only for completing each item in the operation but also required that safety be assured, so it was rather difficult. The first opening for inspection not only examined all of the Chinese-designed special tools to confirm that their performance could satisfy application requirements, but also provided experience for inspecting the opening of the reactor and removal of the fuel. As a result, the field of nuclear submarine power plants in China gained extremely valuable experience in the comprehensive practical process of power reactor design, construction, adjustment and operation, as well as opening and fuel removal.

Chapter 16. Research on Nuclear Science and Technology: Section 5. Research on Uranium Isotope Separation [pp 387-391]

[Text] Enriched uranium needed in the nuclear industry is obtained through uranium isotope separation. Adoption of different separation methods has a direct effect

on the scale, investment and costs of production. This makes research on uranium isotope separation very important for development of the nuclear industry.

1. The cradle of enriched uranium research in China—the Gaseous Diffusion Laboratory for Uranium Separation

To establish and develop the uranium enrichment industry in China, the Gaseous Diffusion Laboratory for Uranium Isotope Separation (referred to simply as the laboratory, below) was established within the Beijing Institute of Atomic Energy during the late 1950's. After it was completed and went into operation in early 1960, the Institute of Atomic Energy soon transferred Wu Zhengkai [0702 1767 6963], Wang Chengshu [3769 2110 2579] and other scientists to strengthen work in the laboratory. This laboratory trained China's first generation of uranium enrichment scientific research and production technology personnel and it did a great deal of work in isotope separation theory as well as technical and experimental research which opened a bright page for the enriched uranium industry in China.

2. Theory, testing, and technical research for applied technologies using the diffusion method

In 1961, the theory group directed by Wang Chengshu in the Gaseous Diffusion Laboratory for Uranium Isotope Separation in the Institute of Atomic Energy (it became the Tianjin Institute of Physical and Chemical Engineering in 1963) spent about a year in organizing theoretical personnel from the Uranium Enrichment Plant and other relevant units as well as some of the professors in the relevant fields at Qinghua University to study theoretical knowledge regarding gaseous diffusion and train the first group of key theoretical personnel for China's uranium enrichment industry. In 1962, the theory group joined with the relevant personnel in the Theoretical Research Laboratory in the Institute of Atomic Energy and through theoretical analysis and a great deal of experimental and technical research, provided important data and experience for startup and operation of the Lanzhou Uranium Enrichment Plant. At the same time, the theoretical personnel in the laboratory also carried out research on steady state and non-steady state cascades. In conjunction with the computing group in the Theory Research Laboratory in the Institute of Atomic Energy, they used electronic computers for a large number of calculations of gas isotope abundance distributions in the cascades, especially curves of variation in U-235 concentrations over time at each point under non-steady state conditions, to provide important reference data for selecting production programs in industrial plants and extraction programs for non-steady state conditions.

This stage also involved experimental research work in the areas of startup and readjustment of the diffusion cascades, cascade program substitution and dealing with the anticipated accidents, performance, maintenance, and inspection of the primary technical equipment and other aspects. In addition, the theoretical personnel in the laboratory studied the related separators and did joint research with the No 7 Academy of Research and Design and production plants to propose new cascade programs. After the Lanzhou Uranium Enrichment Plant began operating stably, the scientific research personnel in the laboratory carried out theoretical research concerning improvements in the diffusers as well as theoretical design of the newly developed diffusers. In 1975, the laboratory completed research on new diffuser cascade dynamics and joined with production plants for cascade economic analysis.

3. Development of separation membranes

Separation membranes are the core components in the gaseous diffusion method for uranium isotope separation and are used in large numbers in a gaseous diffusion plant. Beginning in 1960, China successfully developed several types of separation membranes and provided them for use in gaseous diffusion plants.

In 1960, the Gaseous Diffusion Laboratory for Uranium Isotope Separation established a 14-member membrane development group headed by Qian Gaoyun [6929 4108 7301]. Afterwards, it also organized forces from the Chinese Academy of Sciences, the Ministry of Metallurgical Industry and the higher education system for a major cooperative effort to carry out the work with a division of labor and in a planned fashion. After being examined and approved by the machinery group, the A and B type membranes met the criteria and laid the foundation for China to manufacture its own separation membranes. By 1965, work to develop separation membranes had entered a new stage of improved performance and innovation. In conjunction with the development of new diffusers, research was undertaken on types C and D membranes. Afterwards, forces were organized for attacks on key questions related to the more advantageous type D membranes and this task was completed in 1975. After this, development work focused mainly on the needs in the diffusion industry for development of small-parameter, high-performance membranes, and some achievements were made. Their performance now approximates advanced international levels in some aspects.

Like other research work, membrane development cannot be detached from theoretical research, research on physical performance and chemical performance, and measurement of performance parameters. The Academy of Physical and Chemical Engineering in the Second Ministry of Machine Building Industry, and especially the laboratory before it was moved to Tianjin, assumed primary responsibility for this work. A whole series of experimental facilities and testing equipment was set up for this purpose, including the final link in examination and approval of the separation membranes—the measurement of equal enrichment coefficients for setting up a small cascade. A small cascade is more flexible and can

be operated by adjusting to different conditions as needed. This research created the necessary conditions for development of membranes in China.

4. Research on techniques employing the centrifuge method

The gaseous centrifuge method for uranium isotope separation has been called a second generation commercial uranium enrichment technology. It is very comprehensive and has high technical requirements.

When compared with the gaseous diffusion method, the single-stage separation coefficient of a centrifuge is higher, 1.1 to 1.2, than the corresponding value for the gaseous diffusion method, which is only 1.002. For this reason, to obtain uranium at equal concentrations, the number of cascades in the centrifuge method is about two numerical grades smaller than the gaseous diffusion method. The centrifuge method consumes little electricity and the amount of power consumed per unit of separation capacity is one-fifth to one-tenth that of the gaseous diffusion method. Centrifuge separation, however, requires that the rotor of the centrifuge rotate at a high speed. This means that it is subject to limitations by materials and technologies for manufacturing rotating cylinders, so the unit separation capacity of a centrifuge is rather small. The number of centrifuges required for a plant is much greater than the number of diffusers required for a diffusion plant of identical production capacity. In comparative terms, higher demands are placed on the operation and maintenance of a centrifuge plant.

China has been doing research on centrifuge technologies for over 20 years, beginning in 1958. In the early period, Qinghua University, Beijing University, the former Shanghai Light Bulb Plant and other units were engaged in this work. They overcome many technical problems, took the first steps in scientific research on centrifuge technologies and laid the foundation for faster development in the future. Since the mid-1970's, the Second Ministry of Machine Building Industry has reinforced work in this area and after nearly 10 years of effort China has formed a preliminary and rather complete scientific research staff. It has made many scientific research achievements and the scientific research and development work are moving forward quickly.

5. Research on other separation methods

(1) Research on applied technologies for the laser method

The laser method for uranium isotope separation refers to separation on the basis of the principle of differences in the element absorption wavelengths of the isotopes. It is a new separation method that has industrial prospects. Compared with the diffusion and centrifuge methods, it has the advantages of requiring fewer investments and consuming less power. This is especially true of its ability to use low-grade chemical uranium as a target for enrichment and its higher utilization rates for uranium ore resources. The laser method for uranium isotope separation can be divided into the molecular method and the atomic method.

In the early 1970's, research on using the molecular method for laser separation of uranium isotopes was done in the Changchun Institute of Optics and Precision Mechanics in the Chinese Academy of Sciences, the Dalian Institute of Chemistry and Physics, the Beijing Institute of Electronics, the Academy of Physical and Chemical Engineering in the Second Ministry of Machine Building Industry and other units. To develop research on laser isotope separation using uranium hexafluoride as the medium, the vibration spectra of sulphur hexafluoride, uranium hexafluoride and other materials was studied. In 1976, in a uranium hexafluoride laser separation simulation experiment, sulphur hexafluoride molecules were used as the separation medium. Separation of S-32 and S-34 was achieved and some experimental data was obtained. At the same time, a TEA CO_2 laser and a carbon tetrafluoride laser were used for some basic experiments on uranium hexafluoride. Some effects were observed and some useful data was obtained.

Research on using atomic method lasers for uranium isotope separation also has been done by the Changchun Institute of Applied Chemistry, the Shanghai Institute of Optics and Precision Mechanics, the Beijing Institute of Electronics, the Academy of Physical and Chemical Engineering and other units. They carried out theoretical analysis, laser measurements and other work, and they did a demonstration experiment on uranium isotope separation in 1985 and they measured a rather high separation coefficient.

(2) Research on technological applications of the chemical method

Uranium isotope separation with the chemical method usually refers to the use of chemical exchange methods to separate the uranium isotopes.

The chemical method produces low-grade uranium, consumes little electricity and does not require fluoridization or defluoridization technologies. The cascades have a definite flexibility, the product can be regulated as needed according to requirements and it makes full use of the raw materials. It is, however, only suited to small-scale production. This method is represented by the solution extraction method and an ion exchange method.

In 1958, Wuhan University, Beijing University and other units carried out research on chemical method separation of uranium isotopes. After 1970, the Academy of Physical and Chemical Engineering in the Second Ministry of Machine Building Industry, the Beijing Institute of Uranium Ore Dressing and Smelting and the

Institute of Atomic Energy explored ion exchange membrane electrodialysis methods and ion exchange resin method uranium isotope separation. By the mid-1980's, a valence four and six ion exchange method attained a rather high displacement speed of 40 cm/hour in a small experimental column. Moreover, the preliminary work indicates that in constant valence state exchange systems, a macrocyclic ether extraction system (like crown ether) can produce a rather high single cascade enrichment coefficient. 12539/08309

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